ESTONIAN UNIVERSITY OF LIFE SCIENCES
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BIOFLOC TEHNOLOOGIA KUI ALTERNATIIVNE VESIVILJELUSPRAKTIKA BANGLADESHIS

BIOFLOC TECHNOLOGY AS AN ALTERNATIVE AQUACULTURE PRACTICE IN BANGLADESH

Master´s thesis
Agri-food business management

Supervisor: Ants-Hannes Viira, PhD

Tartu 2021

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Kreutzwaldi 1, Tartu 51014</td><td colspan="2">Magistritöö lühikokkuvõte</td></tr>
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ETIS-e teadusvaldkond ja CERC S-i kood: S187
Juhendaja: Ants-Hannes Viira, PhD
Kaitsmiskoht ja -aasta: Tartu 2021</td></tr>
<tr><td colspan="4">Bangladesh on üks kõige tihedamalt asustatud riike maailmas ning rahvaarvu kiire kasvu ja inimasustuse laienemise tõttu vähenevad kalakasvatuseks sobilikud veekogud. Seega on toidu tagamiseks ning nälja, vaesuse ja töötuse leevendamiseks vaja laiendada ja intensiivistada vesiviljelust uuendusliku tehnoloogia abil. Biofloci kala tanki tehnoloogiat, mis põhineb jääktoitainete ringluse ja mittevoolava vee kontseptsioonil, peetakse kulutõhusaks, keskkonnasõbralikuks ja jätkusuutlikuks vesiviljelusviisiks. Suurema kalakasvu ja ellujäämismäära, suure kalade asustustiheduse ja madalamate söötmiskulude tõttu võib see tehnoloogia suurendada vesiviljelussektori tootlikkust ja tagada selle jätkusuutlikkust. Kuna selle uuendusliku tehnoloogia levik on Bangladeshis alles algusjärgus, on selle vesiviljeluspraktika edendamine ja kasutuselevõtt kriitilise tähtsusega. Niisiis on tõhus teadmussiire ja tootjalt-tootjale õppimine selle tehnoloogia pikaajalise kasvu ja kasutuselevõtu jaoks ülioluline. Infrastruktuuri arendamine, valitsuse poliitika ja toetus võivad vähendada selle tehnoloogiaga seotud ebakindlust ning sellest võivad kasu saada nii tootjad kui ka tarbijad.</td></tr>
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Estonian University of LifeSciences Kreutzwaldi 1, Tartu 51014		Abstract of Master's Thesis	
Autor: Mohammad Soyebur Rahaman		Curriculum: Agri-food business management	
Title: Biofloc technology as an alternative aquaculture practice in Bangladesh			
Page:70	Figure:34	Table:5	Appendixes:2
Department : Institute of Economics and Social Sciences Field of research and (CERC S) code: S187 Supervisors: Ants-Hannes Viira, PhD Place and date: Tartu 2021			

Bangladesh is one of the most densely populated countries in the world and due to rapid growth of population and expansion of human settlement water bodies for fish production are shrinking. Thus, intensification of aquaculture with the help of innovative technology is required to ensure nutrition and alleviating hunger, poverty and unemployment. Biofloc technology, which is based on the concept of recycling waste nutrients and zero water exchange, is considered as a cost effective, environment friendly and sustainable way of aquaculture. With higher growth and survival rate of fish, high stock density and lower feed cost this technology can increase the productivity of aquaculture sector and ensure sustainability. As this innovative technology is still at the early stages of diffusion in Bangladesh, promotion and adoption of this aquaculture practice is critical. So, effective information exchange and farmer-to-farmer learning are critical for the growth and adoption of this technology in the long-term. Infrastructure development, government policy and support can reduce the uncertainties about this technology and that can benefit both farmers and consumers.

Keywords: Biofloc technology, Aquaculture practice, Innovation in aquaculture

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INTRODUCTION

The aquaculture sector has been the most dynamic and productive industry in recent years and has a tremendous prospect in upcoming days for the agricultural economy of Bangladesh. Bangladesh is enriched with huge diversified natural fisheries resources broadly categorized into inland and marine fisheries. Fish is the most important source of protein in regular Bangladeshi diet contributing almost 60% overall of animal protein and per capita fish consumption is recorded 62.58gm which exceeds per day protein demand of 60 gm. According to Yearbook of Fisheries Statistics of Bangladesh, 2018-19,total fish production in Bangladesh has risen by almost six times in the last three decades (7.54 Lakh MT in 1983-84 to 43.84 Lakh MT in 2018-19). Aquaculture production has been more than doubled from 10.63 lakh MT in 2008-09 to 24.89 lakh MT in 2018-19, demonstrating steady growth.

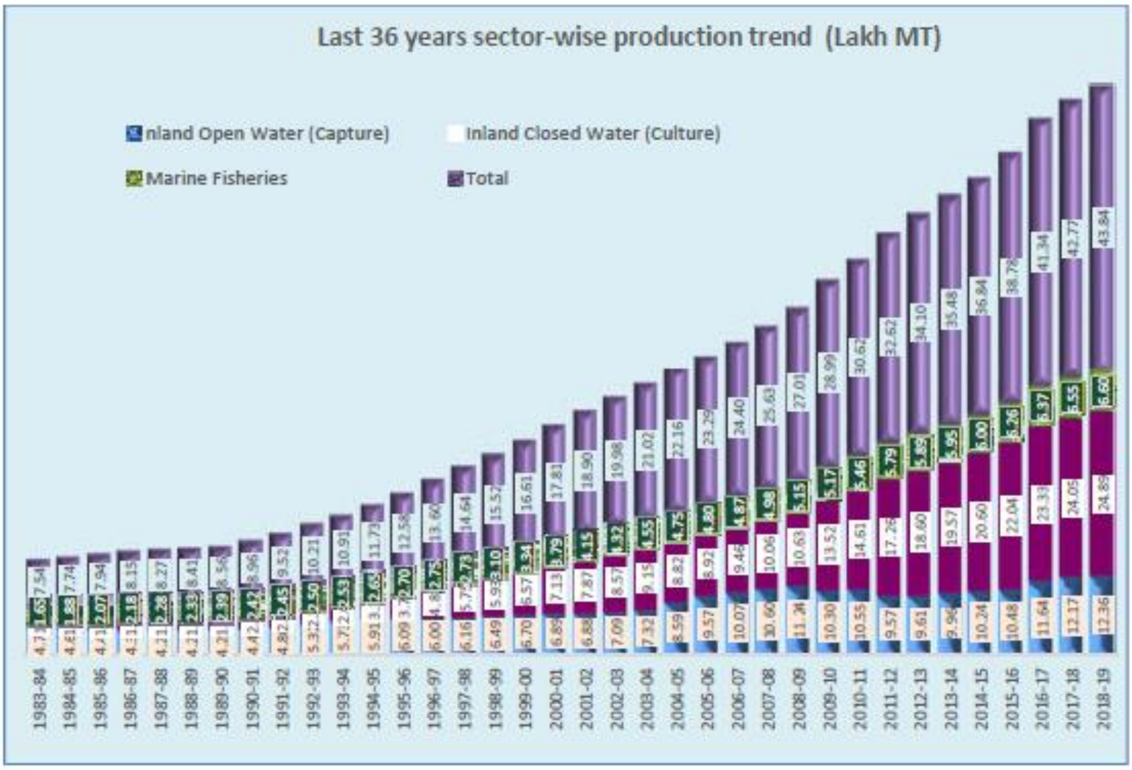

Figure 1: Last 36 Years fish production (Lakh MT), Yearbook of Fisheries Statistics of Bangladesh, 2018-19

A number of special programs aimed at increasing productivity have recently been launched. The program included the implementation of biological open water management, community-based fisheries management, the establishment of beel, nurseries, the stocking of fingerlings, including endangered species, the restoration of fish habitats to facilitate breeding and migration, the establishment and maintenance of sanctuaries for biodiversity conservation, and the expansion of cage and pen farming in environmentally feasible areas. **(Dof 2019).**

Bangladesh is the eighth most heavily inhabited country in the world (Al Hasan et.al 2020) with almost 164 million populations. The population growth rate in is still higher and is expected to grow and will reach approximately 185 million by 2030. In this situation, supply and consumption of two staple foods rice and fish will be affected and will have a major public health implication.

Water bodies are shrinking for fish production due rapid growth of population and expansion of human settlement. Despite this, sustainable growth is still possible with the use of recent improved technology and quality inputs that lead to a significant increase in productivity to meet the demand for a growing population.

Moreover, considering the fact of growing population, an upward trend exists in the demand for aquatic food and it’s really important to scale up the efforts to ensure food security by increasing the productivity through intensification and expansion of aquaculture production. Besides, the ever increasing rate of unemployment and underemployment of educated youth is of huge concern. Average national unemployment rate is 4.2 per cent but it’s 11.2 percent for university graduates and 2.7 percent for those who completed up to primary level. **.** (Rahman et al. 2021). If this trend of unemployment continues, it is estimated that in the next ten years, the number of working-age residents in Bangladesh might grow more than two million per year. As the rate of employment opportunity is lagging far behind, unemployment might be a reason for new social unrest and maladies in the country. (Rahman et al. 2021).

So, intensification of aquaculture with the use of modern technology might offers ample opportunities to create employment, accelerates economic growth, better utilization of natural resources and helps in poverty alleviation and reduce hunger and malnutrition (FAO, 2017). In recent years, although a substantial progress has been made towards ensuring nobody needs to go starving and food security for the huge population has been

achieved, still ensuring the consumption of healthy and nutritious diet for population remains a challenge .Unfortunately, Bangladesh is among the highest in the world in term of rates of malnutrition. Almost more than 9.5 million children that are 54% of total preschool-aged kids are stunned, 56% are underweight and around 17% are wasted Alam, S. N., & Naser, M. N. (2020).
However, intensification and expansion of the aquaculture industry is challenged by inadequate availability of natural resources and adverse environmental impact from the industry. (Dreccer, *et al.*, 2012; Verdegem, 2013) Adverse environmental impact includes discharge of huge amount of nutrients from aquaculture production system especially in the form of nitrogen and phosphorus. Verdegem, M. C. (2013).

So the ultimate goal is the expansion of aquaculture industry for higher productivity and profitability without increasing the use of available natural resources like land and water (Avnimelech, 2009) as well as development of a sustainable aquaculture system with a lower impact on environment. Moreover, the cost benefit ratio should be taken into consideration to ensure social and economic sustainability (Avnimelech, 2009).

Figure 2: Biofloc Fish farm In Bangladesh (Source: Framers)

There is an increasing interest among people towards closed aquaculture technology because of having biosecurity and environmental advantages over traditional semi-intensive and extensive systems. (Nahar, et al. 2015).So, by taking all these issues into consideration, Biofloc technology is an emerging prospect in improving aquaculture productivity and is considered as an environment friendly, cost effective method and eventually contribute to achieve sustainable development goals. (Khanjani, M. H., & Sharifinia, M. 2020).

The main principle of biofloc aquaculture system is activated suspension technique (AST) that is retaining the waste and transforming it into floc as a feed in the culture system. For this, the water quality is enhanced through a high level of constant aeration and addition of extra external carbon sources as organic substance that helps in aerobic decomposition and maintaining high level of microbial floc. (Azim, M. E., & Little, D. C. 2008).

Aim

The aim of this research is to explore an overview of biofloc technology in Bangladesh and identify who these farmers are, how they are doing and future prospects.

Research tasks

- Review prior research on the development and use of biofloc technology in the aquaculture industry;
- Investigate the potential impact of biofloc technology application to aquaculture production as an environment friendly and sustainable practice,
- Emphasize the importance of developing biofloc technologies for improving aquaculture productivity as an alternative method for aquaculture practices
- Provide guidelines for overcoming the challenges for the development of biofloc technology in Bangladesh.

Research method

This research has been carried out based on both quantitative and qualitative approaches with the use of both primary and secondary data. Primary data were sourced directly from the farmers through questionnaire and interview. Graphical and statistical presentations were used to represent the data derived from the questionnaire and the interview data were presented as narrative analysis. The respondents were drawn from social media platforms like Facebook and wthatapp groups of the farmers and from known sources.

Secondary data were collected from previous literatures, journals, Yearbook of Fisheries Statistics of Bangladesh, department of fisheries (Dof) -Ministry of fisheries Bangladesh website and Bangladesh bureau of Statistics (BBS),

1. LITERATURE REVIEW

1.1 Nutrition in Bangladesh and related challenges

In developing countries of the world malnutrition is pervasive and it is estimated that almost one half of total South Asian children and one-third of Africa are undernourished. It's really a concerning issues as childhood nutrition is considered as the foundation for survival and development of current and future generation. (Deolalikar, A. B. 2005). In rural areas of Bangladesh, adolescents usually have a monotonous diet habit with rice that accounts for almost 76% of energy intake and only 3% for animal source food. So it is obvious that diets of adolescent girls are poor as well lacking necessary nutrients. (Leroy et al 2018).

Weight gain throughout the adolescence roughly accounts for 50% of total adult weight and approximately 15% of adult height is grown during this time. So lack of proper nutrition might have a long term consequences for adult health. But, for girls adolescences nutrition is related with their health, survival and their children's well-being. (Leroy et al 2018).

Almost one-third of rural women in Bangladesh are malnourished and 36% of kids under 5 are stunned (Ahmed et al. 2012) and this high depth malnutrition has a significant and long-standing consequences for economic and human development.

Education level of household head was identified to have a significant effect on child nutrition. Households with more educated heads were associated with less hunger and better nourished children. On the other hand, less educated household heads were associated with more hunger and eventually results in undernourished children. (Cooper et al. 2019).

Households in rural areas with less access to superior transportation facilities and food markets usually have lower agriculture productivity and (Stifel and Minten 2008) and children in such regions are mostly affected by geological precipitation patterns and eventually have higher rate of stunting. (Thapa and Shively 2018).

Previous studies had found high rainfall as a reason for stunting in that country. (Rodriguez-L lanes et al. 2011) Changes in precipitation patterns due to changing climate predictably have major influences on nutrition and food security in rural areas in developing countries (Cooper 2019). Increased rainfall has always been associated with more hunger in Bangladesh. This is not at all unexpected that flooding in Bangladesh is a reason for food insecurity and increased rate of food insecurity. (Douglas 2009; Mirza, M. M. Q. 2002). Rainfall always has a mixed influence in relation with food security as it might results in higher food production and more agricultural income. On the other hand, it might obstruct food utilization due to increased disease and pest burden. (Cooper, 2019).

In the long term, stunting and wasting can influence educational outcomes, disease risk and possible adult income (Badham and Sweet 2010; Dewey and Begum 2011).To reduce this rates of the indicators of malnutrition and under nutrition is crucial for sustainable development. (Daelmans et al. 2017).

A substantial progress has been made in Bangladesh to reduce malnutrition and poverty over the last two decades until now a lot of indicators related to food security and malnutrition remain high. (Rahman 2010; Rahman and Salim 2013)

In an article by Leroy et al 2018, improvement of quality of diet was highlighted as an urgent pre-requisite in Bangladesh for both adolescent boys and girls and for adult women as well. Moreover, lack of diversity and heavy dependence on rice were identified as the most influential drivers for poor quality diet in Bangladesh.
Diversification in agro-production systems might results in improvement of the quality of diet as well as benefits to the environment. (Frison E. A. 2006).

Leroy et al 2018, concluded, for the improvement of nutrition status and dietary intake of teenage boys and girls, household's accessibility to diverse diets should be increased through policies and programs. Simultaneously, social norms and beliefs with respect to adolescent nutrition are required to be addressed carefully through social behaviour change interventions.

1.2 Aquaculture Practices in Bangladesh and related Challenges:

With world's biggest flooded wetland Bangladesh is considered as one of most suitable areas for fish production and after China and India it has the third largest marine biodiversity in Asia (Shamsuzzaman et al. 2017). In addition, with its rich river systems and inland waters, Bangladesh has substantial capture fishery and tremendous aquaculture prospective. Moreover, the favourable geographical location of Bangladesh comes with a great number of fish species and delivers a lot of resources to support aquaculture potential. (Shamsuzzaman et al. 2017).
Bangladesh is rich in water resources with inland water bodies of almost 4.5 million ha including reservoirs, baors or oxbow lakes, marshes, rivers and estuaries. (Chakraborty *et al.*, 2005). Baor or oxbow lake is semi-closed water bodies engaged by dead channels of the rivers in the diminishing delta of the Ganges. It's basically a semicircle lake that is designed at a curve of a river or a canal that altered or departed its course since several decades but the water is still noticeable at the curve of the river. There are around 600 oxbow lakes in the southwest region of Bangladesh with a combined area of approximately 5488 ha. (Halim et al. 2018).

Baors are usually leased to individuals or co-operative through open auctions and People now has converted baors as culture fisheries. Species like rui, catla, tilapia, silver carp, black carp and some other fishes are now cultured in most of the baors. Fishes produced in baors plays an important role for the supply of protein to people of the country and for support of livelihood, poverty alleviation. A great number of fishermen depend on activities related to the fishery and meet their household nutrition requirements for fisheries activities in baors. (Halim et al. 2018).Moreover, Bangladesh has a marine and costal environment that is considered as one of the world's richest ecosystems, blessed with an extraordinary warm tropical climate and plenty of rainfall and high productivity.

The coastal fisheries sector in Bangladesh has potential but not utilized rationally rather the resources have been over-exploited and the fish stock is declined (Shamsuzzaman et al. 2017). Recently Bangladesh has attained a maritime boarder by ''International tribunal for the Law of the seas'' that ensures a reasonable manner and privileges for fishing and has opened a new prospect of fishing in that area.

Bangladesh has one of the wealthiest coastal and marine zone ecosystems in the world with greater productivity and distinctive mangrove influences. The contribution of marine fisheries resources is really crucial for the economy accounting almost 16% of total fisheries production.

In Bangladesh, two types of aquaculture are mostly practiced, freshwater and costal. Generally fresh water culture is the farming of indigenous and exotic carps, catfish and cichlids in the pond and accounted for more than 80% of the overall recorded aquaculture production. (Shamsuzzaman et al., 2017).Other common freshwater culture areas are oxbow lake, cultures in seasonal water-body like paddy field and flood plain. On the other hand, coastal aquaculture mostly includes farming of shrimps and prawn in coastal enclosures and pond or culture in cage and pen. (DoF, 2017).

The fisheries in Bangladesh are broadly divided into three subdivisions: Inland culture, inland capture and marine fisheries. However, inland water resources offer a huge prospect in term of fresh water culture and capture fisheries. (Hossain, 2014). The total catch from inland capture fisheries is really significant, especially for people from rural areas in terms of their employment and supply of fish. On the other hand, inland culture is also noteworthy contributing almost more than 56.76% of total fish production in Bangladesh. (Yearbook of Fisheries Statistics of Bangladesh 2018-19)

Among a number of fisheries sub-sectors, inland aquaculture has the fastest growth due to establishment of new aquaculture technologies, intensified and improved farming and species. It is estimated that more than 2% of total export value derives from inland fisheries. With proper support from government, fisheries sector has huge potential in generating different types of supplementary industries especially in rural areas with a high rate of return. (Shamsuzzaman et al. 2020)

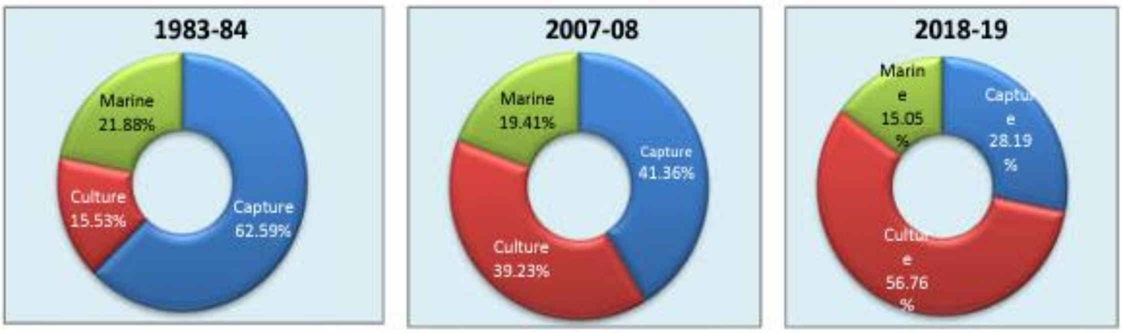

Figure 3: The contribution of inland capture, culture and marine fisheries to total fish production (Yearbook of Fisheries Statistics of Bangladesh 2018-19)

Among all marine fish species, Hilsa fish (Tenualosa ilisha) is the most valuable single species of Bangladesh as hilsa catch made up almost 12% of total annual production (4.134 million metric tons) in the year 2016-2017.Over the last 12 years, the production of Hilsha has almost been doubled due to government's initiatives including execution of Jatka (Small Hilsha) conservation program and implementation of protection activities of hilash spawning. The total annual value of Hilsa fishery is 1.3 billion USD and accounts for more than 1% of total Bangladesh's GDP and approximately 2.5 million people are directly and indirectly employed in the process. Hilsha has enormous significance from social and cultural point of view and is privileged as the national fish of Bangladesh and an inevitable part of many social, religious and festive events (Mozumder et al. 2018).

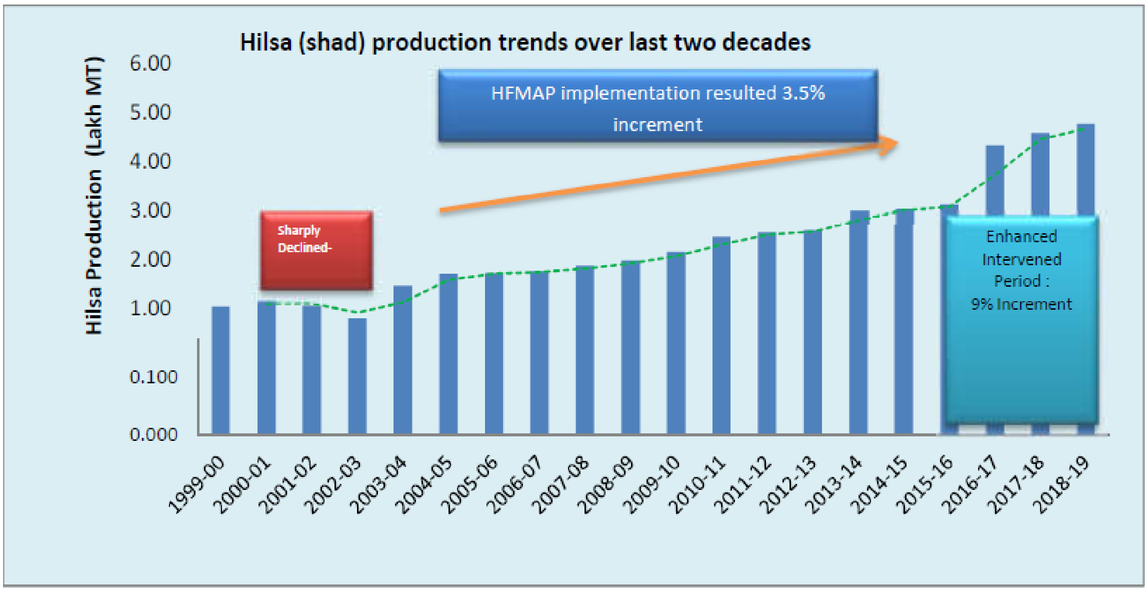

Figure 4: Hilsha Production Over last 12 Years, Yearbook of Fisheries Statistics of Bangladesh 2018-19.

Because of over exploitation of fish using harmful fishing gears and fishing systems like fishing by dewatering, decrease of fish habitats, gradual increase of agriculture production and construction of roads, water pollution, introduction of new invasive fish species inland fish stocks declined significantly and the baors are at present in vulnerable condition and total fish production is declining day by day. (Ali *et al*. 2009)

Future growth in aquaculture really important in providing sustainable fish supplies for human nutrition, creating employment and ensuring food security for rapidly growing population. But, climate changes and variability are major challenges to aquaculture as it depends mostly on availability and quality of natural resources and especially on the water (Islam et al. 2019).

Vulnerability induced by climate might vary from region to region, geographic areas, system of aquaculture and which species is farmed. Coastal areas are more likely to more be unprotected to climatic dangers compared to inland areas. In Bangladesh, 45 out of 64 districts are inland and 19 are coastal districts (MoWR, 2006). Inland areas are mostly affected by flood, precipitations and temperature however the coastal areas are also affected by these three along with a rise in sea level, wave height and land erosion (Zsamboky et al. 2011).

Compared to coastal areas, inland areas might not always be more protected from climatic hazards. To develop plans to deal with disasters and hazardous impact of climate change, the coastal areas has been the fastest while climate change is not included in inland region hazard plans (Babcock, 2013). Bangladesh, with its 64 districts processes various geographical features and faces different climatic disasters and hazards. For example, north western part of Bangladesh suffer from prolonged drought and acute shortage of water due to climate change but central and north-eastern part are endangered with frequent flood and river erosion and coastal regions are vulnerable to cyclones, tidal surge, saline intrusion and rise in sea level (Shamsuddoha & Chowdhury, 2007).

Increased water temperature can change pond environment by shifting the level of dissolved oxygen that creates detrimental algal blooms and increased number of parasitic diseases. (Karvonen et al. 2010). Toxic substance like cyanide, xylene, phenol zinc etc. that exists in water demonstrates toxicity at high temperature. Higher mortalities have been reported because of algal blooms during summer time. On the other hand, lower temperature causes mortality during winter_particularly in smaller fish with less energy reserves compared to larger conspecifics (Rijnsdorp et al. 2009).

Natural resources face numerous sustainability challenges such as degradation, imbalanced and unfair use and exploitation Holland, Marjorie M 1996).The negative impacts of poorly managed sustainability challenges on natural environment adversely affect human society through a range of composite feedbacks and exchange process and the impact of this sustainability challenges might be overarching. For instance, almost one third of global fisheries are overexploited (Finkbeiner, et al 2017, FAO, Ed 2016).This overexploitation of fisheries is a threat for all level of social resilience both in global and local scale specifically for people who directly depend on for livings, food stuff and well-being.

1.3 Overview of Biofloc technology

1.3.1 Principle of biofloc technology

Biofloc technology is based on the concept of recycling waste nutrients, especially nitrogen, into microbial biomass, which can either be used in situ by cultured animals or harvested and transformed into feed ingredients (Avnimelech, 2009). The practice of nutrient regeneration is the fundamental concept of this approach It is originated based on the continued addition of carbon and nitrogen to pond water (Avnimelech et al.1994) To promote the growth of heterotrophic bacteria and generate microbial biomass, a carbon/nitrogen (C/N) ratio is managed (Avnimelech, 1999).

Biofloc technology is a method of improving water quality by using additional external carbon sources in combination with high levels of aeration in order to achieve high levels of microbial bacterial floc in aquaculture systems. Maintaining a carbon-to-nitrogen ratio greater than 10 is critical in this scheme, and can be accomplished by adding carbon-containing organic materials such as molasses, wheat flour, starch, or lowering the protein level of the feed to maximize heterotrophic bacteria growth.

This technology is effectively based on zero water exchange meaning that no water exchange is needed inside the culture ponds; as a result, it requires less water intake, which is not only cost-effective for farmers, but also reduces pathogenic animal entry into water, ensuring greater biosecurity in the fish culture. Water substitution is no longer necessary because ammonia can be kept at a low, nontoxic concentration. Biofloc technology improves efficiency and sustainability by ensuring the availability of high-quality fish juveniles, which is one of the most significant inputs in the process.

Large-scale aquaculture production with biofloc systems may have environmental advantages in marine and coastal environments, and aquaculture wastewater and its environmental impacts can be managed by replacing soybean or fish meal in aquatic feed with floc compounds.

1.3.2 Biofloc and its preparation

Generally, Biofloc is a macro-aggregation of bacteria, fungi, detritus, and other decomposed components (Avnimelech et al., 1994) It is made up of bacteria, diatoms, zooplankton, protozoa, macro-algae, feces, uneaten feed (Fig. 1), and the exoskeleton of deceased species (Decamp et al., 2008) . It's a group of biotic and abiotic particulate components dissolved in water that contains bacteria, planktons, and other organic materials (Hargreaves, 2006)

Biofloc is formed by combining organic carbon with high aeration, which eliminates harmful dissolved nitrogen in the water, where internal waste disposal systems are encouraged and emphasized. (Liu et al. 2019). Hargreaves (2013) described the biofloc as "a combination of algae, bacteria, protozoans, and other kinds of particulate organic matter including feces and uneaten feed, as well as some zooplankton and nematodes, developed together to form an interconnected and interdependent ecosystem." particles

It includes organic material compounds (60–70%), a heterogeneous mixture of microorganisms (fungi, algae, bacteria, protozoa, rotifer, and nematode) and inorganic substances (30–40%) such as coal (Chu & Lee 2004). During biofloc formation, the color changes from green to brown as bacteria mature due to the transition from algal to bacterial in a BFT environment.

To generate biofloc, the tanks are first filled with water, then a certain volume of nitrogenous content such as aquatic feed and urea fertilizer are added to provide the nitrogen, and finally carbonate organic materials such as molasses, wheat flour, starch are added to complete the process. After softening and going through the sieve, clay is applied to the microbial reservoirs to aid in the formation of the microbial mass (53-lm-sized particles or less pass with mesh number of 270). Clay should be added at the start of the biofloc formation process to help maintain mass consistency. Aeration is performed after the requisite elements were added to the system in order to activate the function of bacteria in the water.

During the biofloc forming cycle, algae first grow and then foam phase, and the emergence of a brown state indicates the presence and behavior of heterotrophic bacteria. During the experimental time, when aquatic animals are present in the tanks, the physicochemical parameters (temperature, oxygen, pH, alkalinity, total nitrogen, ammonium, nitrite, and nitrate) should be measured and suitable responses, as illustrated below, should be implemented as soon as possible.

Bioflocs have a complex nutrient benefit (Ekasari et al. 2010) and can serve as a full aquatic food source while also including bioactive compounds (Ahmad et al. 2017). Biofloc use and recycling in the culture system improve feed production (Hargreaves 2006).Beneficial nutrients such as protein, lipids, essential fatty acids, minerals, vitamins, carotenoids, and digestive enzymes are provides by biofloc that aid digestion and thereby increase nutritional status.

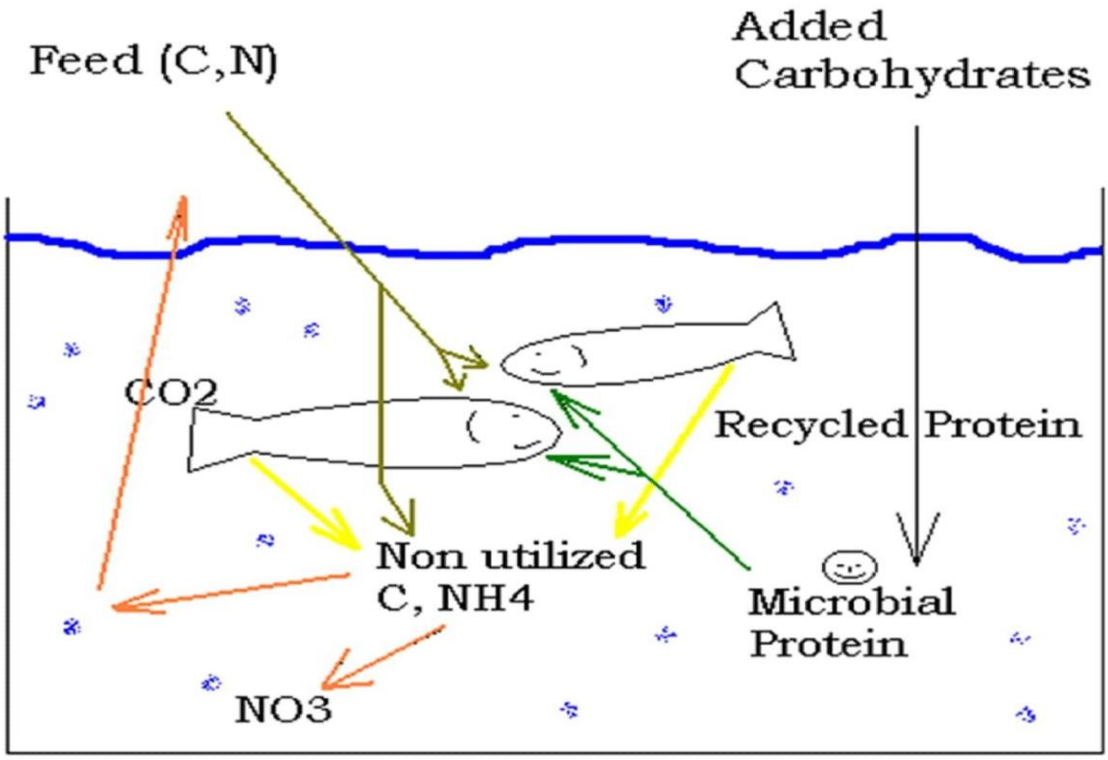

Figure 5: Activated Biofloc tank (Source: Google)

1.3.3. Impact of biofloc on feed efficiency, growth performance and immunity

In the aquaculture industry, lowering production costs and increasing profitability are significant goals. Aquaculture costs are influenced by growth rate and feed conversion ratio, which are lower in the biofloc system than in the traditional system, and profitability is higher in the biofloc treatments. Aquaculture management costs include better feed recycling; a higher feed conversion ratio, and a higher real growth rate and survival rate. Survival rate and other biological parameters are important variables in cost return and profitability. Because of the decrease in commercial feed demand and the utilization of biofloc, the biofloc scheme is more profitable than the clean water system, resulting in lower food prices.

Since biofloc would be a feed for the cultivable livestock, the feed demand is significantly reduced, resulting in a lower FCR. As a result, farmers' feed costs will be reduced as a result of the technology's implementation. Biofloc improves fish longevity because the protective microorganisms that predominate in it serve as an antagonist to pathogenic bacteria, preventing disease outbreaks and increasing the number of fish that survive the harvest. This way, the (beneficial) bacteria found in the biofloc inhibit the invasion of any dangerous bacteria, ensuring that the fish in the farms have the best chance of survival.

Immune system of shrimp has been found to be improved in the presence of bioflocs, and shrimp raised in biofloc systems have lower chances of disease. The impacts of bioflocs on the fecundity of shrimp and tilapia have been shown in new research: in both cases, the number of eggs per female was nearly doubled.

This might be due to the high efficiency of the biofloc feed ingredients, improved water quality, or the presence of hormones (or of components having hormonal effects). Biofloc technology is now widely used in the operation of hatcheries and nurseries. Furthermore, biofloc systems are environmentally sustainable since nutrient-rich irrigation water is almost never released into the atmosphere

Incorporating biofloc into a popular carp's diet resulted in a 75 percent increase in growth and digestive enzyme activity (Najdegerami et al. 2016). In addition, using biofloc as a dietary supplement at 4% in tiger shrimp feeding improves growth and digestive enzyme activity (Anand et al.2014).

Azim and Little et al. (2008) conducted an analysis to assess Tilapia growth and fish yield parameters where Tilapia survival was 100% in all treatment and controlled tanks. Individual fish weights were 9–10% higher in the BFT treatments than in the control group at harvest. Specific weight gain and net fish production were 44–46 percent higher in the BFT treatments than in the control, confirming that biofloc is used as food by fish.

Biofloc contains a large number of beneficial bacteria that help in the improvement of animal immunity. Further data suggests that the animals cultured in biofloc water had a substantial increase in non-specific immunity. It is considered that the presence of heterotrophic microbial biomass in the biofloc works to prevent pathogenic bacteria from invading.

1.3.4. Waste treatment and managing water quality through biofloc technology

The success of fish farming entirely depends on the physicochemical and biological qualities of water. As a result, for optimal pond management, water quality control is needed The ratio of nitrogen (N) to carbon (C) in the water during the aquaculture cycle can be monitored by using active biofloc technology (Avnimelech 2009).The biofloc technology works to improve the physicochemical parameters of water to an optimal range are critical for proper growth of fish and shrimp (Sharma et al. 2018).

Waste treatment infrastructure is normally needed in high-density fish and shrimp culture, and biofloc is the best waste treatment solution. BFT systems were found to be effective in increasing fish productivity by forming a positive relationship between biofloc and fish density, which revealed a higher capacity to recycle nitrogenous waste at high culture densities (4 million fish per ha) (Park et al. 2017).

Adoption of biofloc technology helps overcome the issues associated with ammonia toxicity. As heterotrophic bacteria consume more nitrogen, the nitrification method progresses, it ensures a decrease in ammonium concentration in culture systems

(Hargreaves, 2006). Biofloc waters are high in heterotrophic bacteria that use toxic nitrogenous matter as a substrate for growth, which helps to sustain water quality by lowering organic loads and the system's biochemical oxygen demand (Avnimelech, 1994; Burford et al., 2004; Wasielesky et al., 2006)

Because of the large number of feeds used, fish and shrimp ponds have a heavy nutrient load and there is excess of carbon and nitrogen in the culture pond as almost 50–70% of feeds end up in the water or in the sediment that makes water quality to deteriorate. Biofloc technology can increase water quality in fish and shrimp ponds by combining carbon and nitrogen in the aquaculture environment by photosynthesis and nitrification processes (Crab et al. 2012). The optimal carbon and nitrogen ratio in biofloc was reported to help sustain water quality for raising Pacific white leg shrimp in lower salinity for inland culture. As a result, the risk of land degradation from the discharge of salty drainage from the shrimp pond is reduced (Kumar et al. 2019).

1.3.5. Biofloc technology for biosecurity and sustainable environment

Increasing aquaculture production by vertical and horizontal expansion releases an unacceptable amount of contaminants in the ecosystem. Biofloc technology (BFT) applications are one of the best aquaculture systems that help to meet sustainable growth and clean-environment goals.

This technology is based on zero water exchange, which means that no water exchange is needed in the culture ponds. As a result, it requires less water intake, which is not only cost-effective for producers, but also reduces pathogenic animal entry into water, ensuring greater biosecurity in the fish culture. It also promises to have less negative effects on environment and create fewer footprints. (Wasielesky et al. 2006)

BFT technology, as compared to conventional aquaculture techniques, offers a more efficient solution with limited water exchange and decreased feed consumption, transforming it into a low-cost sustainable technology for aquaculture production. Using this method can minimize water exchange while increasing density and biosecurity. Farm biosecurity and biofloc technology are two major factors that must be addressed for intensive aquaculture sustainability. BFT improves biosecurity by limiting water exchange, increasing environmental control (Ju et al. 2008).

Biofloc technology has a number of advantages over other modern fish farming methods, including an environmentally sustainable culture system with no drain water after culturing. BFT is preferred over other schemes because of its higher capacity of reducing environmental effects, improving the optimal utilization of land and water, maintaining suitable water quality with minimum water consumption and exchange within the rearing ponds. Furthermore, under high stocking density of fish or shrimp, biofloc systems can work with zero to low water exchange (0.5 percent to 1 percent every day), making it an optimal method for water conservation (Hargreaves 2013).

1.4. Theoretical background on adoption and diffusion of innovation, investment and new entrepreneurs in agri-food supply chain

A concept or practice that potential adopters consider as new is referred to as an innovation (Rogers, E. M. 2010). Innovations that help in adaptation in aquaculture sector include changes in materials, technical and informational dimensions practices. The technical and material dimensions received the highest attention from researchers of aquaculture innovation and adaptation as the practice of these innovation and changes are always associated with concern of diseases and intake of lower quality water as well as continuous pressure from regulatory authority to minimize the discharge of polluted water (Turcios, A. E., & Papenbrock, J. 2014).

Promotion of agricultural innovation among smallholders in developing countries remains critical to poverty reduction and an important means of improving food security, production, and wages (Spielman,Ekboir, & Davis, 2009). Social, technological, and structural influences may either help or hinder innovation (Moore & Westley, 2011).

The rate at which an invention is adopted is supposed to be influenced by five characteristics: (1) relative advantage; (2) compatibility; (3) complexity; (4) trial ability; and (5) observe ability (Rogers, E. M. 2010). Importantly, rather than quantitative facts, the choice to adopt (and therefore the pace of diffusion) is dependent on prospective adopters' subjective expectations.

For adaption in the aquaculture field is innovation is considered as one of the "enabling factors" (Soto et al. 2019). Technology-driven, structural, and business-managerial methods have been used to study aquaculture innovation, with the first being by far the most prominent, according to (Joffre et al. 2017). Technology-driven methods provide insight into technological success as well as explanations for non-adoption (Kumar et al. 2018), but they depend on basic hypotheses about who teaches (scientists, engineers), and what gets moved (Kumar et al. 2018). Systemic approaches can help understand which aquaculture systems are dominant and what conditions are needed for transition but they can't explain why those innovations aren't implemented due to a lack of fit with daily life (Hargreaves et al. 2013). Business management techniques emphasize the relevance of creativity for a firm's competitiveness (Zainol et al. 2016). Yet they are less adept at catching progress of intent, such as for sustainability.

Who adopts and adapts is determined by costs, skills, experience, and risk perceptions, as these factors influence whether a change in practice is deemed worthwhile or not; however, which options are visible and considered is often influenced by structuring conditions, which in mainstream aquaculture strongly favour standardization of rearing practices and products, making it critical to introduce more adaptive practices unless they are low-cost, no regrets options. As a result, in order to mobilize innovation for adaptation, consideration must be extended to who supports, obstructs, and who innovates for whom (Lebel, L. at el. 2020).

Farmers-led methods are increasingly seen as a viable way to promote the rapid spread of more efficient, accessible, and sustainable agricultural practices in rural contexts, in reaction to the well-documented constraints of technology transfer in the 1980s (Thompson, John, and Ian Scoones 2009). Community resource users collaborate with scientists and extension agents to create contextually appropriate innovations in farmer-led approaches.

Although many academics believe that sustainable aquaculture innovations would spread through farmer-to-farmer knowledge transfer (Brummett, Randall E 2011), few studies have explicitly tracked the adoption of aquaculture by small-scale farmers, especially in the Pacific context.

Entrepreneurship is a process in which businesses engage in arbitrage or innovative activities in order to find, identify, and exploit new profit opportunities (Ross, R. B. 2011). But, globalization, technological innovation, and market segmentation have resulted in an increasingly complicated agri-food supply chains and networks, as well as unstable agri-food markets .In situations marked by volatility, market segmentation, knowledge intensity, and hyper competition, businesses that embrace and develop entrepreneurial talents are more likely to thrive (Bettis, et al., 1995; Ross, R. B., & Westgren, R. E. 2008). However, government funding for agriculture has declined significantly in recent decades, leaving many small-scale farmers lacking access to critical inputs and extension services (Thompson et al. 2009 and Blythe, Jessica L 2013). As a result, effective information exchange and farmer-to-farmer learning are critical for the growth and adoption of long-term agricultural innovations.

Biofloc is an innovative idea in Bangladesh and it's not long ago that people started to know about this technology .So adoption and diffusion of this technology involves uncertainties and requires more researches and investment. Moreover entrepreneurs and participation of stakeholder in agri-food supply chain are crucial for this technology to be accepted.

2. METHODOLOGY

2.1 Data collection

Questionnaire:

This study was conducted based on primary data. A questionnaire was prepared to derive data directly from the biofloc fish farmers in different areas of Bangladesh. Based on previous literatures on biofloc technology, the questionnaire was structured in such a way that it can explore in-depth information about the farms, production and marketing and overall operations.

The initial part of the survey questionnaire was designed to obtain demographic information of the Biofloc farmers e.g. name, age, education level, location of farm. The next part (Question 1 to 25) was about the description of the farm, capacity, production, harvest and marketing, financial outcome, government support and future plan with the biofloc farm. At the end, an open ended question (No.26) was asked to explore the barriers for developing biofloc technology in Bangladesh.

The questionnaire was made using goggle form and was sent to the farmers through emails, whatsapp and Facebook messenger and was available for the farmers to respond from June 20, 2021 to July 25, 2021 .The contacts of the farmers were collected from different Facebook groups of biofloc farmers in Bangladesh.

The survey questionnaire was sent to around 500 farmers of which a total of 31 farmers responded and got around 28/29 valid responses. The reasons behind lower number of responses are that most of farmers in Bangladesh are not willing to share their personal or business information and many of them are scared of malware and data hack while responding over online platforms. Moreover, due to Covid-19 pandemic there was hard restrictions and lockdown in Bangladesh that hindered the opportunity to visit the farm on the spot.

Interviews:

In addition to questionnaire, five semi-structured interviews were conducted as the number of respondents were not many and for additional insights or new phenomenon about biofloc technology, framers and farms. On the other hand Interviews are always play a crucial role as it helps in getting relatable stories, perspectives and lots of qualitative data that helps avoiding embellishment, maintaining the integrity of research content and certainly assisted in validation of results.

Semi-structured interviews were involved asking almost same set of survey questions to the interviewees and related additional questions were asked to explore in-depth information about drivers, activities and operation of biofloc technology.

The interviews were conducted over whatsapp, Facebook messenger call and the notes of the conversation were taken during the interviews. For each interview session it took around 45 minutes. The interviews were conducted from July 20, 2021 to July 31.The contacts of the interviewees were managed from different Facebook groups of biofloc farmers who are directly involved in aquaculture using biofloc technology.

2.2 Data analysis

Data that were derived from questionnaire were analysed, interpreted and presented in graphs, pie charts and bar charts using Microsoft excel spread sheet. The use of regression analysis was also used to analyse the relationship between some variables and R studio was also used to get the correlation coefficient of some variables. Some data sets like age of the farmers, capacity of the farm, total annual production were grouped into different range for better analysis and presentation, for example the ages of the respondents were grouped (20-25 years, 26-30 years, etc.) and that of the annual production was grouped into (below 1000, 1001-1499, 2000-2499 etc. all in kilograms).

The following hypotheses were tested in this research to determine the relationship between sufficient income, experience in fish farming and training in biofloc. The null hypotheses are.

1. **H_0:** There is no relationship between sufficient income and experience in fish farming.

H_1: There is a relationship between sufficient income and experience in fish farming

2. **H_0:** there is no relationship between sufficient income and training in biofloc.

   H_1: there is a relationship between sufficient income and training in biofloc.

3. **H_0:** there is no relationship between sufficient income and number of tanks used by the farmers.

   H_1: there is a relationship between sufficient income and number of tanks used by the farmers.

4. **H_0:** there is no relationship between financial outcome and the future plan of the farmers.

   H_1: there is a relationship between financial outcome and future plan of the farmers.

Regression analysis shows the degree relationship (correlation) between the dependent variable and the independent variables. The regression model used here is the linear regression also known as ordinary least squares. Here the analysis was done to determine the relationship between the responses on the dependent variable is "sufficient income" and the independent variables experience in fish farming and training on biofloc. The responses with "Yes" were changed to 1 and those with "No" to determine the relationship between those that stated that they have sufficient income and having experience in fish farming and training in biofloc. The regression analysis was performed using Microsoft Excel.

On the other hand, information obtained from interviews were presented as a narrative analysis that involves highlighting critical points of respondent's individual stories that best resonate with my readers and area of research. The heighted keywords and findings from the interviews are added as extra insights while discussing the survey questions at the result at chapter 3.

3. RESULTS

3.1 Description of respondents

Age distribution

The analysis of age distribution of the biofloc farmers shows that almost 43% of the famers belong to the age group 26-30 years and 29% are from age group 31-35 years. It's clear from the graph that majority (85%) are between age range 20-35 years and only 15% are above 35 years age group. It indicates that at present majority of the population of biofloc farmers are younger generation and involvement of old farmers are really lower.

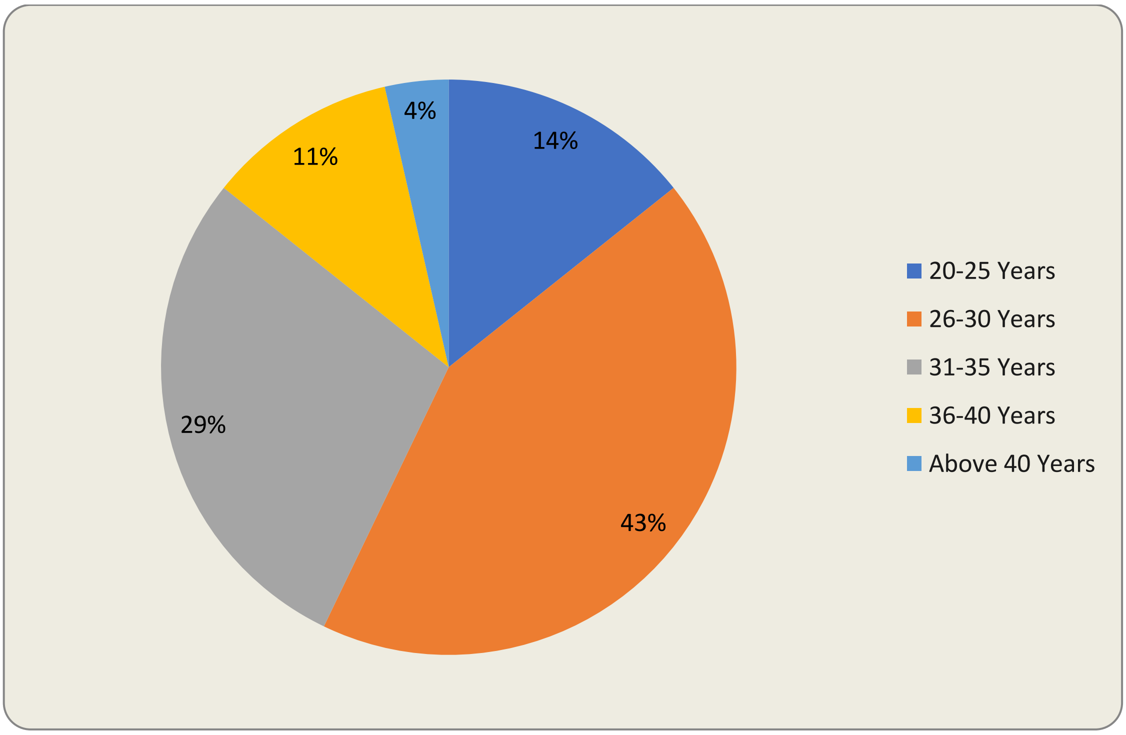

Figure 6 : Percentage Distribution of age of the farmers (n=28)

Gender:

As it is seen from the following pie chart (Figure 7), majority of the respondents are male (almost 93%) and female accounts for only around 7%.It's really common in Bangladesh that usually men are responsible for family income and female are mostly engaged in household activities and participation of female in agriculture or aquaculture in not common at all.

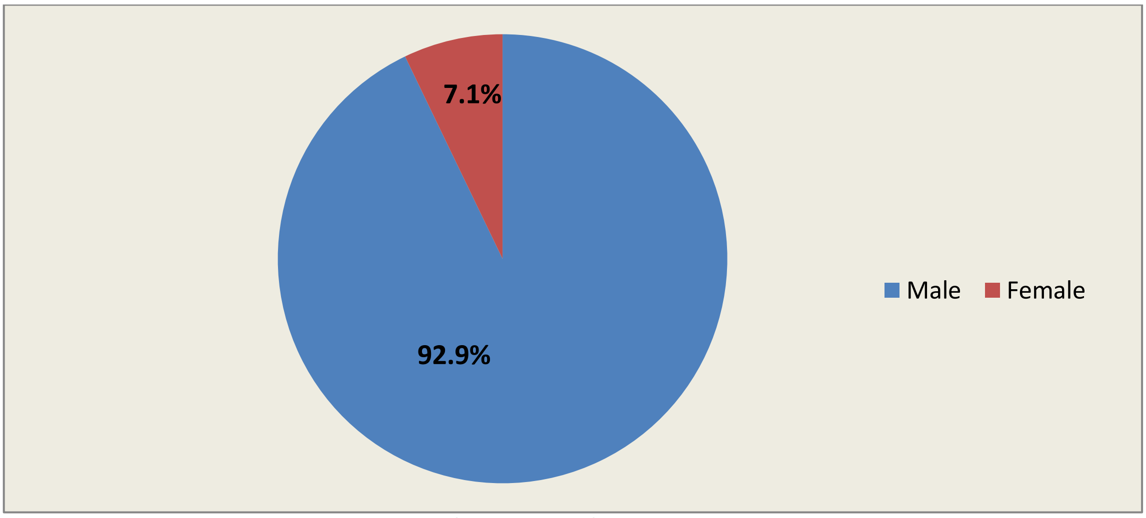

Figure 7: Percentage distribution of Gender of the Farmers (n=29)

Education

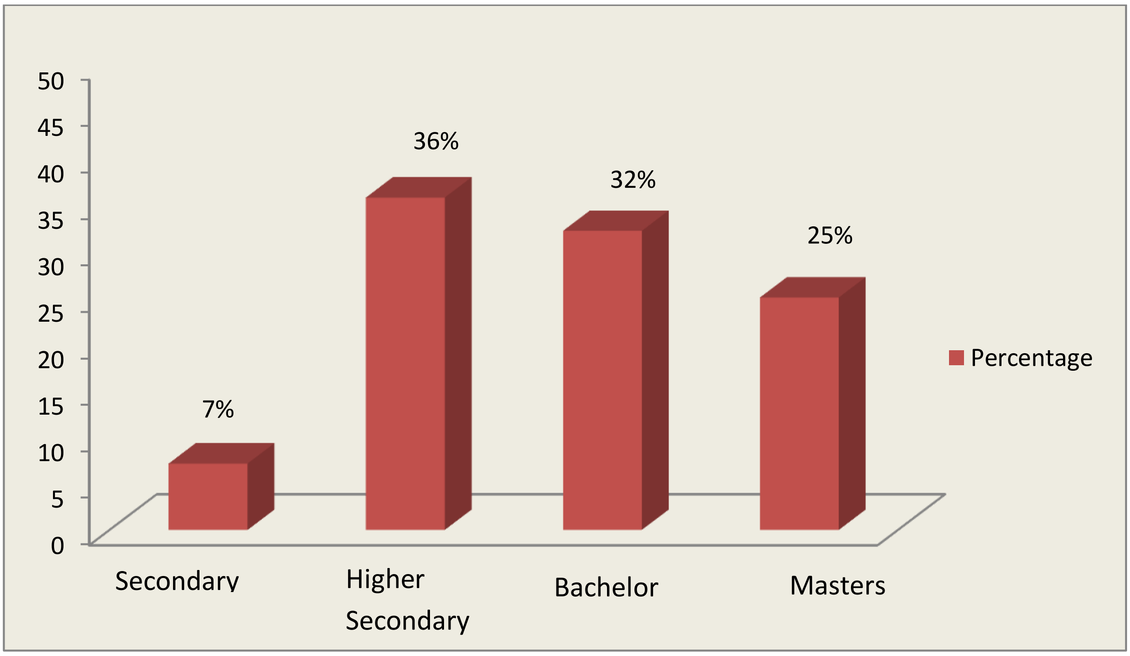

Figure 8: Education level of the Biofloc farmers (n=28)

From the above graph of education level (figure: 8), all the respondents have completed at least secondary level. The number of farmers that represents the highest percentage is up to higher secondary (36%) and bachelor level (32%).On the other hand 25% of the farmers completed their master's degree while only 7% completed their secondary education (10th grade).A lot of farmers who respondent in the survey with higher education is an indication of increased number of educated unemployed people in the country and they trying to adopt this technology not the classical farmers. Moreover it's mostly the educated people who are connected in social media platforms and responded in the survey.

Area:

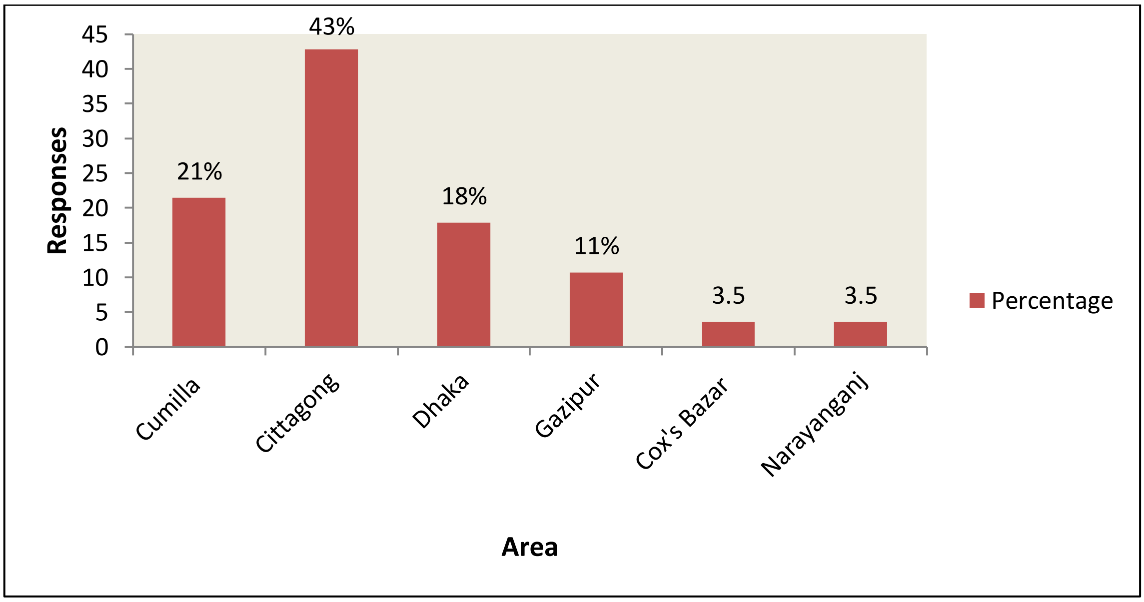

Figure: 9 Location of the farms (n=28)

From the above graph of location of the biofloc farms, 43% of the respondents are from Chittagong, the second biggest city of the country, port city and commercial capital of Bangladesh. This is because of availability of machineries and biofloc accessories in Chittagong as it is the centre of export and import in Bangladesh. On the other hand 21% of the respondents were from Cumilla, another major city while 18% of the respondents are from Dhaka, the capital city of Bangladesh.

3.2. Activity type and Income

Work outside of the Firm?

From the data on Figure: 10 we can see that almost 83% of the farmers are working outside of their biofloc fish farms. So farming enables them to earn extra simultaneously with their regular job or main activities.

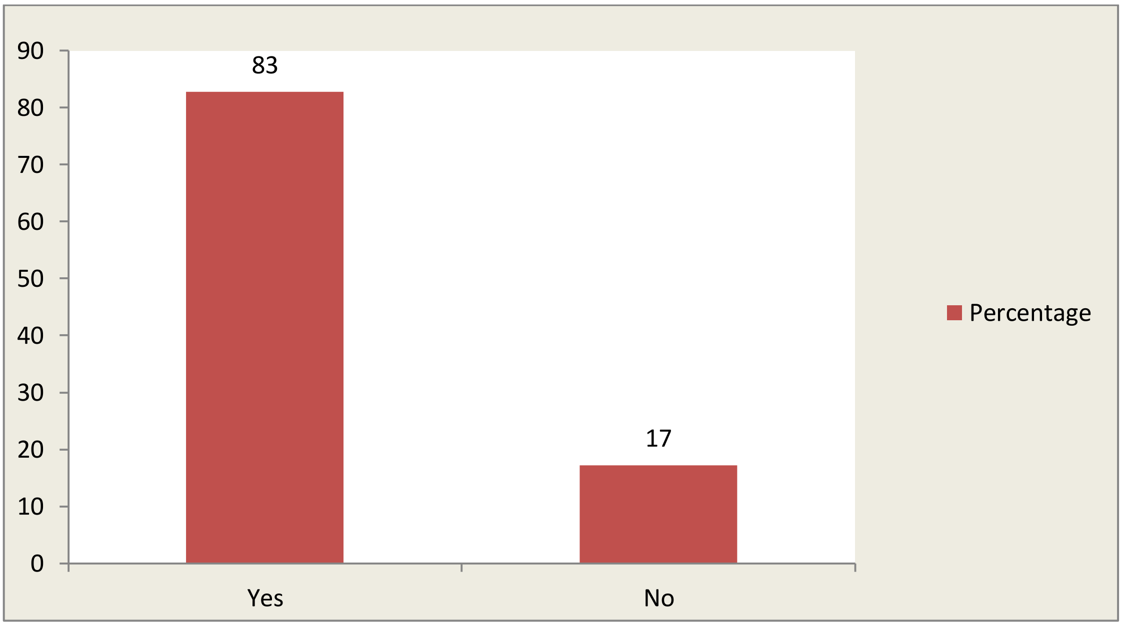

Figure 10: Working outside of biofloc fish farm (n=29)

Main/side activity:

From figure: 11 we can see that biofloc is a side activity for almost 66% of the farmers. Hence boifloc fish farming is not yet considered as a main profession by majority of the farmers.

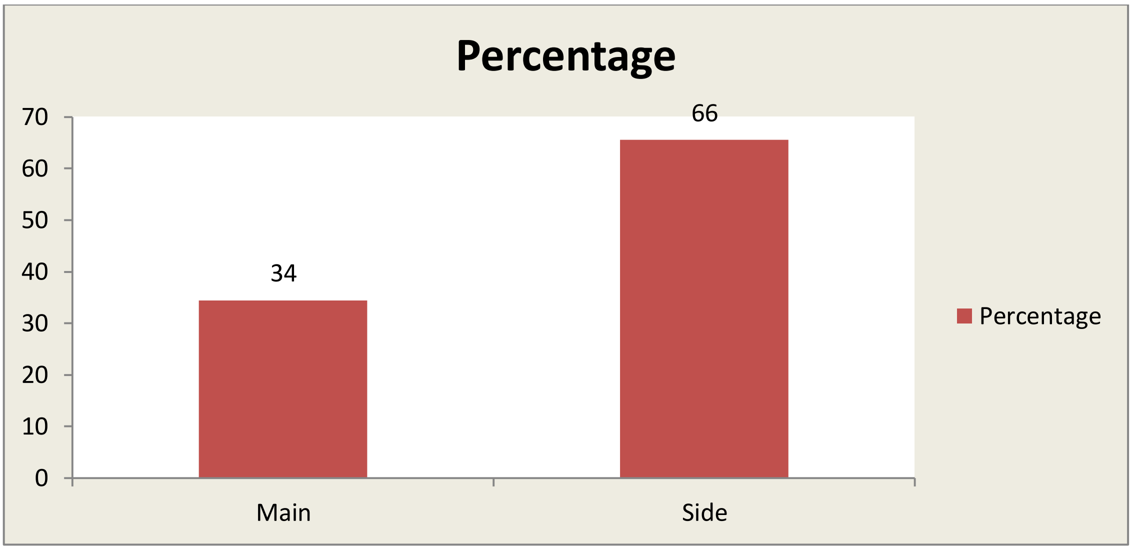

Figure 11: Main or Side activity (n=29)

3.3. Description of farms

Year of establishment

From the survey data on year of establishment of the farm, it's obvious that biofloc technology is at its early stage in Bangladesh. The farmers who responded at the survey started their business in the year 2018 to 2021.

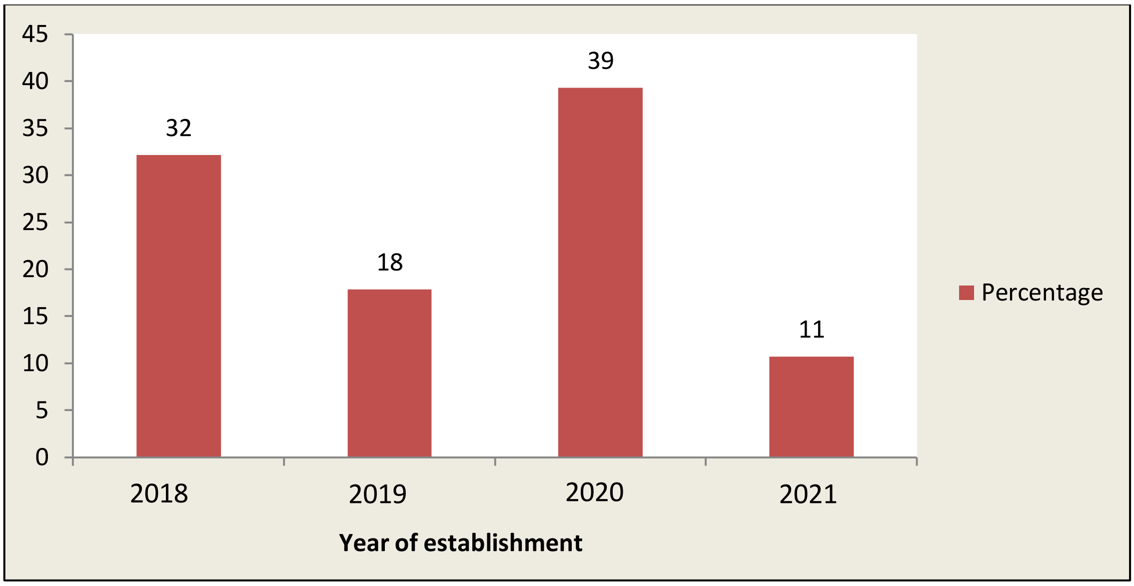

Figure 12: Year of establishment of the farms (N=28)

The information derived from the interview also confirms that biofloc is a new practice in Bangladesh. Most of the respondents were not aware of this technology before 2017 and even though some them were aware of this technology, but had no idea about how to set up this technology and where to collect the machineries and accessories. Use of social media directly influenced in the adoption of this technology as most of the farmers knew about this technology from Youtube and Facebook except some farmers who were influenced by the success story of their friend. Businessmen who started importing biofloc machineries or accessories and some biofloc farmers who started providing training for money also played a part in spreading the idea of biofloc technology in Bangladesh.

Factors that drive the framers in adoption of this technology includes getting some extra income out of their free time after regular work while others started biofloc as an intention of trying something different or new and as a hobby. Moreover unemployment and poverty were also identified as a drive for the adoption of this technology.

Type of business

As it is seen from the graph, almost 90% of the respondents started their business as sole proprietorship while 7.1% started as partnership only 3.5% were registered as a company.

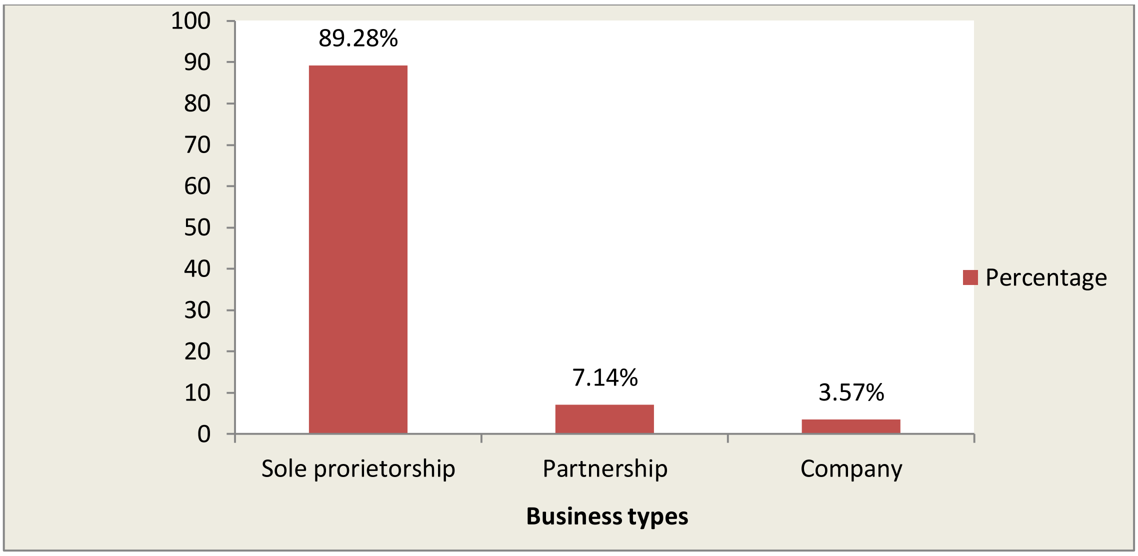

Figure: 13 Types of business (n= 28)

During interview we explored the reasons behind most of the firm's being sole proprietorships where the respondents think sole proprietorship to be easy to start with less formalities of documentation and less costly. On the other hand starting business as partnership or a company is a complex process and requires additional cost and service charges.

Number of employees

While considering the number of employees, in 41% of the farm there are no employees and in almost 34% of the firm, they have only one employee. It clearly indicates that the farms small in size and managed by the owner himself.

Interviews also confirmed that in most farms there are a few or no employees as aquaculture with biofloc technology doesn't have a lot of works except feeding the fish several times and checking water parameters once a day. In most of the farms that are established as a sole proprietorship, family members work as helping hand in absence of the farmer and in partnership farms, the partners take the responsibilities.

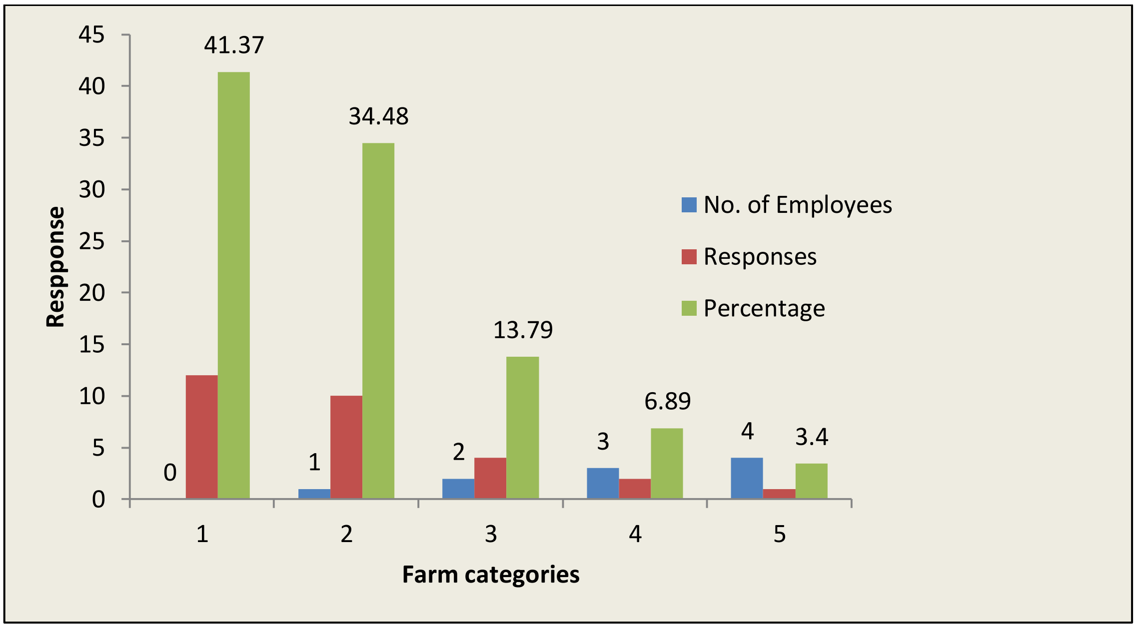

Figure 14: Farm categories according to no. of employees (n=29)

Role of the respondents at the farm:

From previous results, as we can see that most of the boifloc farmers established their farm as a sole proprietorship business and managing their farm's operation by their own. So, in most cases, owners are self-employed at their farm.

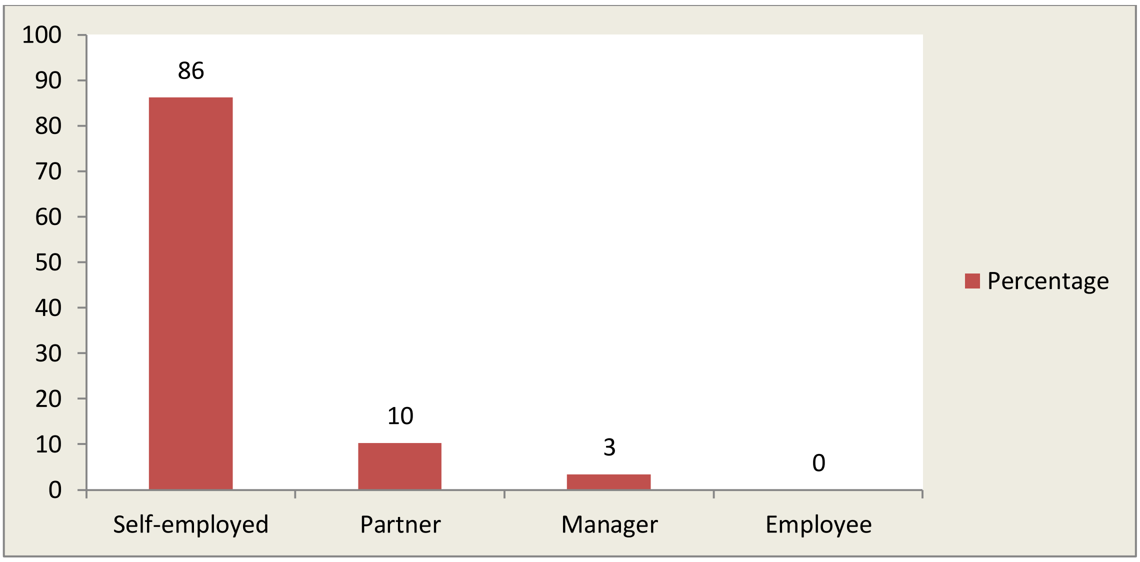

Figure 15: Role of the respondent at the Farm (n=29)

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3.4. Training and experience

Previous experience of fish farming

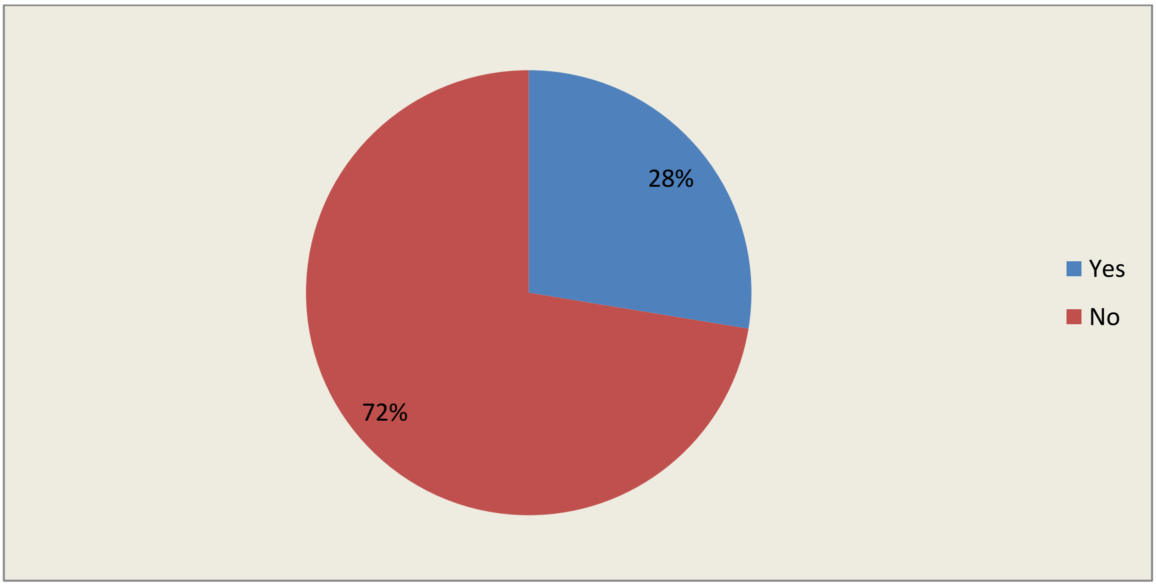


Figure 16: Previous experience of fish farming (n=29)

From the survey data it's visible that most of the respondent (72%) started their biofloc fish farming without having any previous experience of aquaculture. Hence, most of the biofloc farmers are the new entrepreneurs in agriculture sector.

From the interview, respondents informed that, as traditional fish farming is completely different from biofloc fish farming and the experience of conventional aquaculture is not that beneficial for biofloc technology.

Training on Biofloc before starting

As it is seen from the pie chart, 83% of the respondents didn't get any training on biofloc before starting their business. The reason behind this large number of farmers not getting any training before starting their business is that there is lack of professional trainers and approved training center.

During interviews, respondents were asked how they started biofloc without having any experience or training and in reply most of them confirmed that they got the idea from Facebook or watching Youtube .Some of respondents visited biofloc farms of their friend or the neighbour. Another reason for not having any kind of training was that the trainers in this sector are not skilled enough and there are a lot of fraud trainers of biofloc technology.

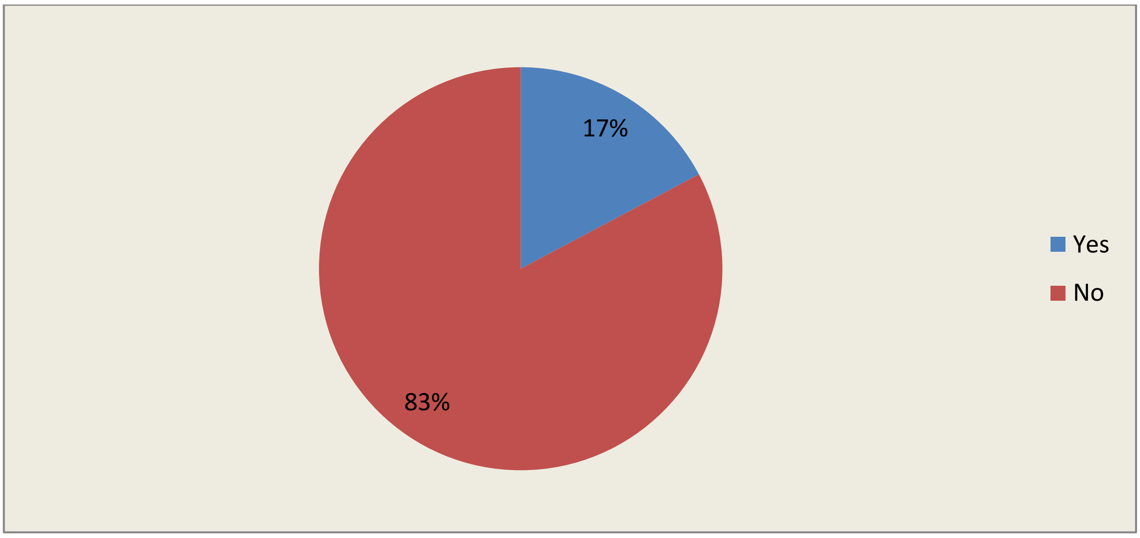


Figure 17: Training on biofloc before starting (n=29)

Information Source:

The research result shows that 40% of the framers rely on the social media platforms for technical information about biofloc technology and the rest (60%) equally depends on local experts or other biofloc farmers. This is clear indication of absence of dedicated institutions to support biofloc farmers with technical information.

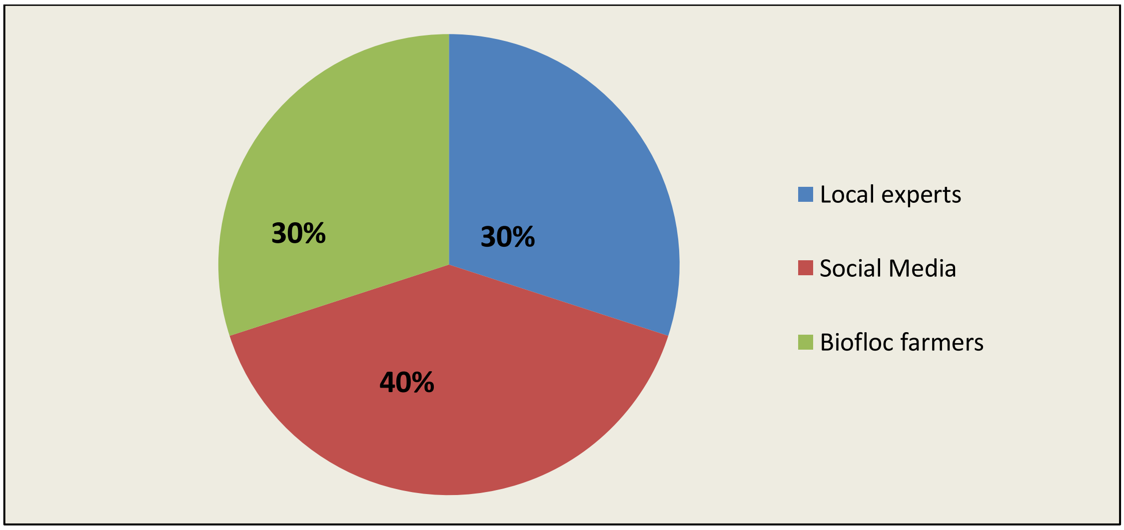


Figure 18: Source of technical information (n=29)

3.5. Production

Number of tanks in a farm

Number of tanks in each farm determines the size and production carried out by that farm. Hence from figure: 16 we can see that majority of the farm (62%) are in small in size with only one fish tank. Only 8% of the respondents have 4 tanks and 4% with 5 tanks. The farmers who have 2 or 3 fish tanks account for 13% in each category.

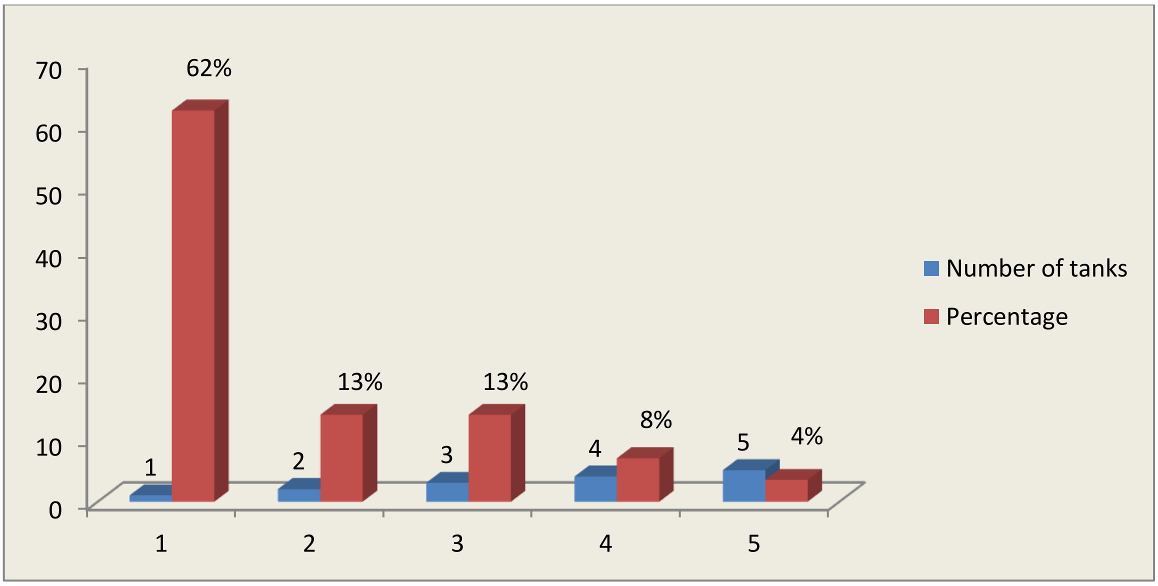


Figure 19: Number of tanks in each farm (n=29)

During interviews, farmers were asked about the reasons behind smaller size of the farm and lower number of fish tanks and most of them started bifloc as an experiment and others don't have the opportunity to increase the number of tanks as current capacity is the highest that they can make out of their free space at their house.

Total capacity of each farm

The analysis of the capacity of each farm indicates that almost 41% of the respondents have a tank capacity of 10000 litres and 28% have a tank capacity of 20000 litres. It's obvious that majority of the farmers started biofloc in a small scale and only 10% of the farmer have a tank capacity of 40000 to 50000 litres.

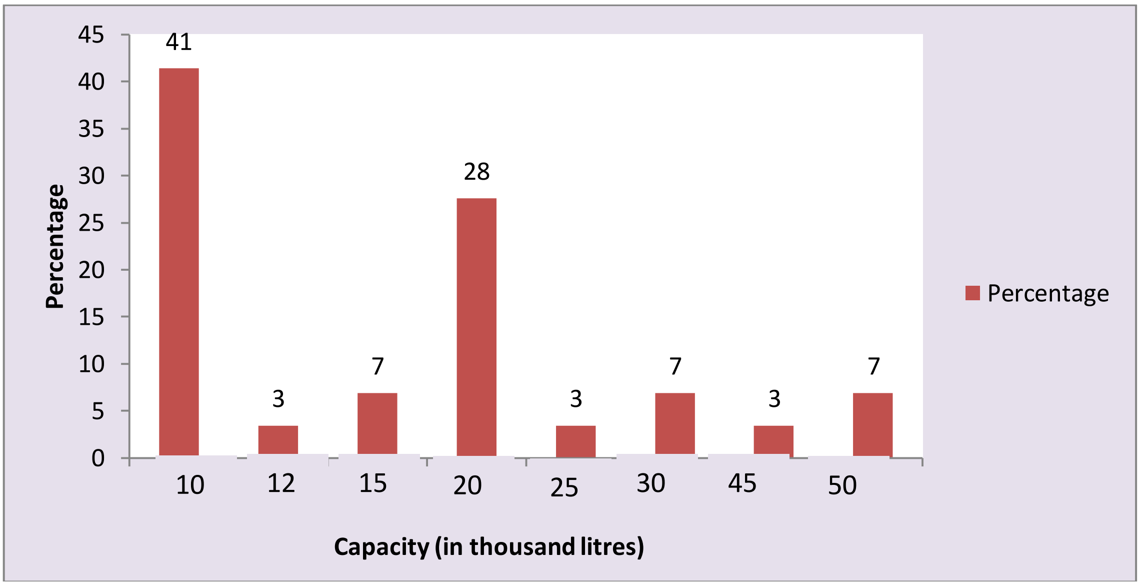


Figure 20: Total capacity of each farm (In thousand litres) n=29

Preferred Fish species

According the survey data, Tilapia is the most preferred fish species to the biofloc farmers as 50% of the respondents choose this species for their biofloc farm and koi that represents the second highest (36%) responses. Furthermore, Shrimp (7%), shing (3.5%), catfish (3.5%) were also preferred by some farmers.

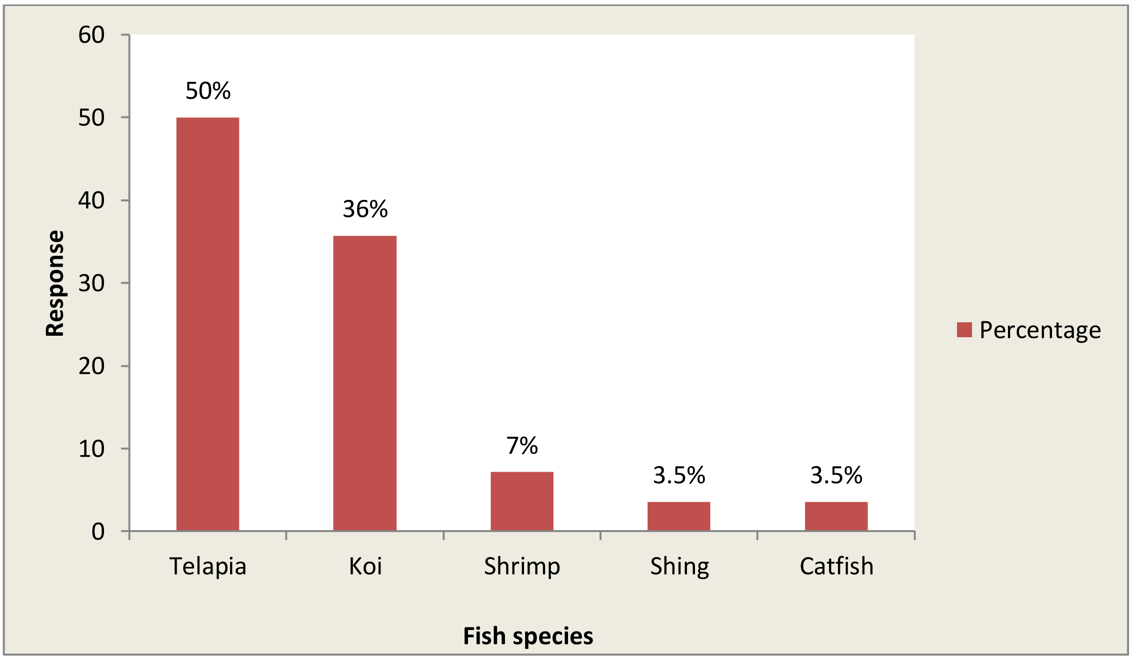


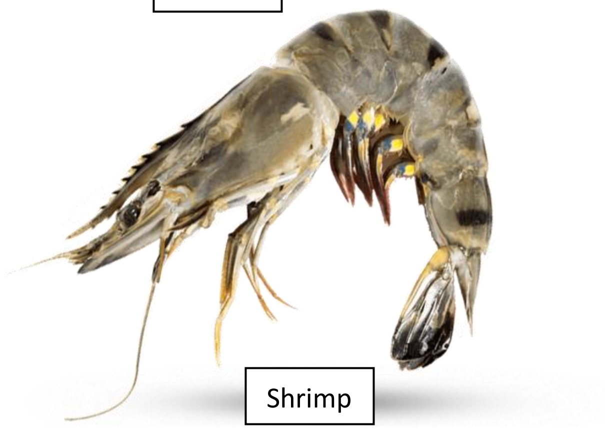
Figure 21: Preferred fish species (n=28)

Information obtained from interview indicates that, Tilapia is preferred for its high growth rate, high demand due to affordable market price, availability of fingerling and three harvests in a year. On the other hand koi is preferred as a native variety and for its high survival rate in case of interrupted aeration due to lack of electric supply. The other species like shrimp, shing are preferred for their high market price.

Koi fish

Shing

Tilapia



Shrimp

Source of fingerlings

All the respondents adopting biofloc technology collect the fish fingerling directly from the local suppliers and don’t like to breed fingerling by themselves. (Figure: 22)

According to information obtained from the interview, breeding of fingerling involves huge expenses as extra equipment and technology is required for this purpose and most of the farmer doesn’t have any idea about breeding.

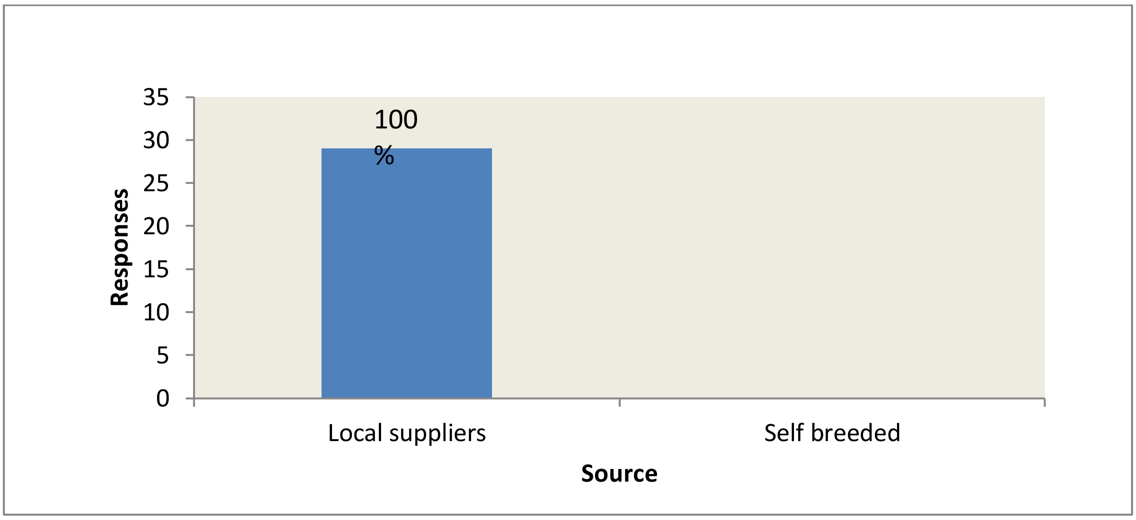


Figure 22: Source of fingerlings (n=28)

Availability of fingerlings

From the survey data, 57% of the respondents think that the fingerlings are easily available while other 43% think opposite.

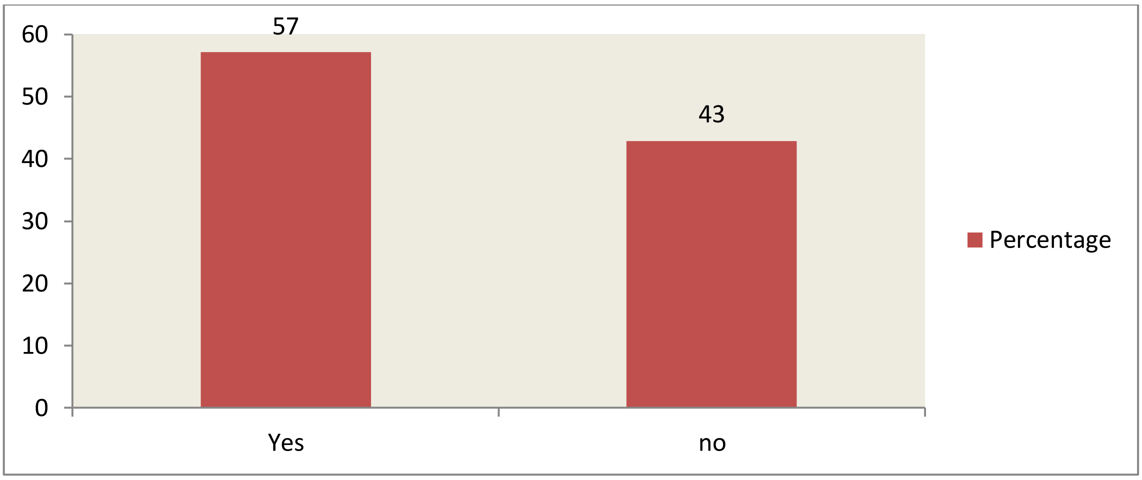


Figure 23: Availability of fingerlings (n=28)

It was also confirmed by the interviewees that, fingerlings are easily available but there is shortage of good quality fingerlings and the farmers are always deceived with the quality of the fingerlings. Sometimes they need to order fingerlings from remote places that involve additional expenses for courier and transportation and its time consuming as well.

Availability and price of accessories:

According to survey results, almost 69% of the total respondents think that the machineries and accessories related to biofloc are easily available in the market while 31% think the opposite.

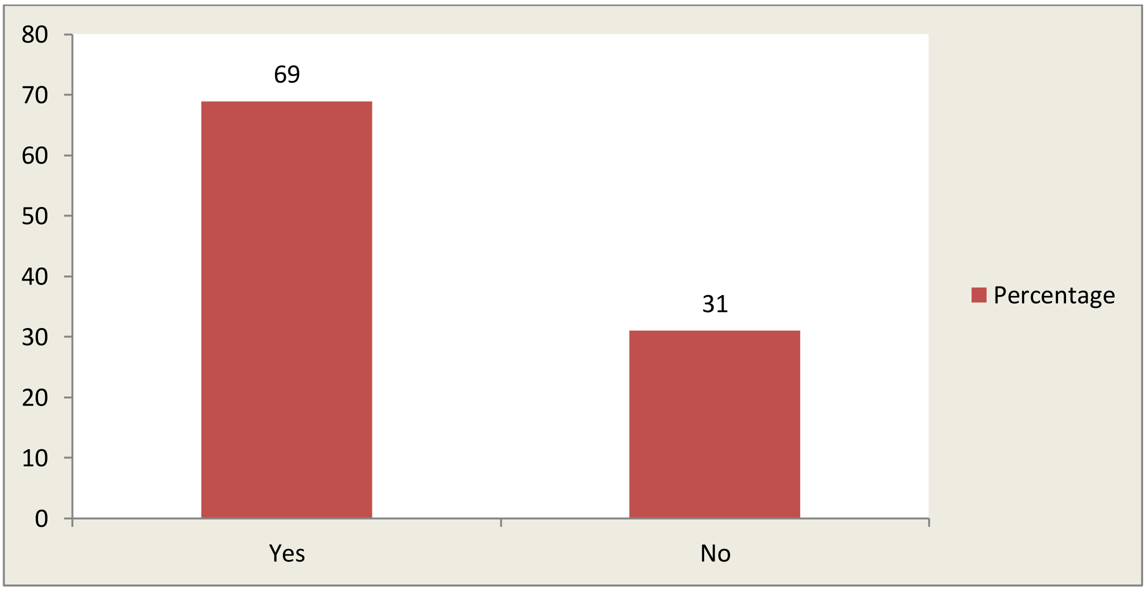


Figure 24: Availability of Machineries (n=29)

Price of machineries and accessories

The survey outcome of data on price of machineries and accessories indicates that almost 52% of the respondents think it to be costly and 41% of the respondents consider it to be reasonable. Only 7% thinks the price to be cheap.

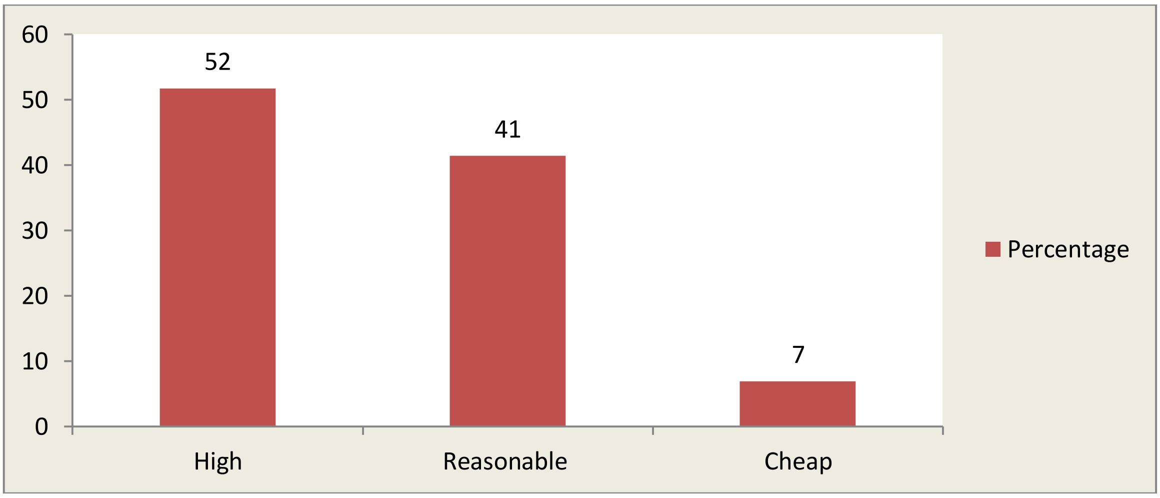


Figure 25: Price of machineries and accessories (n=29)

3.6. Harvest, sales and marketing

Harvest

From the following graph (Figure: 26), 93% of the respondents have the experience of at least one harvest from their biofloc fish tanks and 7% didn't ever harvest. Farmers who didn't harvest ever are basically started their farms in recent times and still waiting for the outcome.

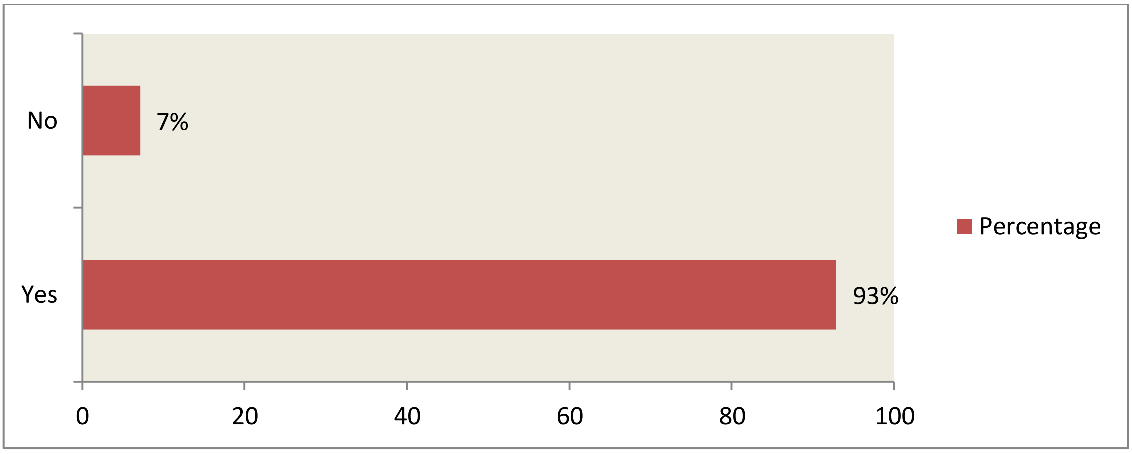


Figure 26: Ever harvested or not? (n=28)

Average production from each harvest from a tank (In kilogram)

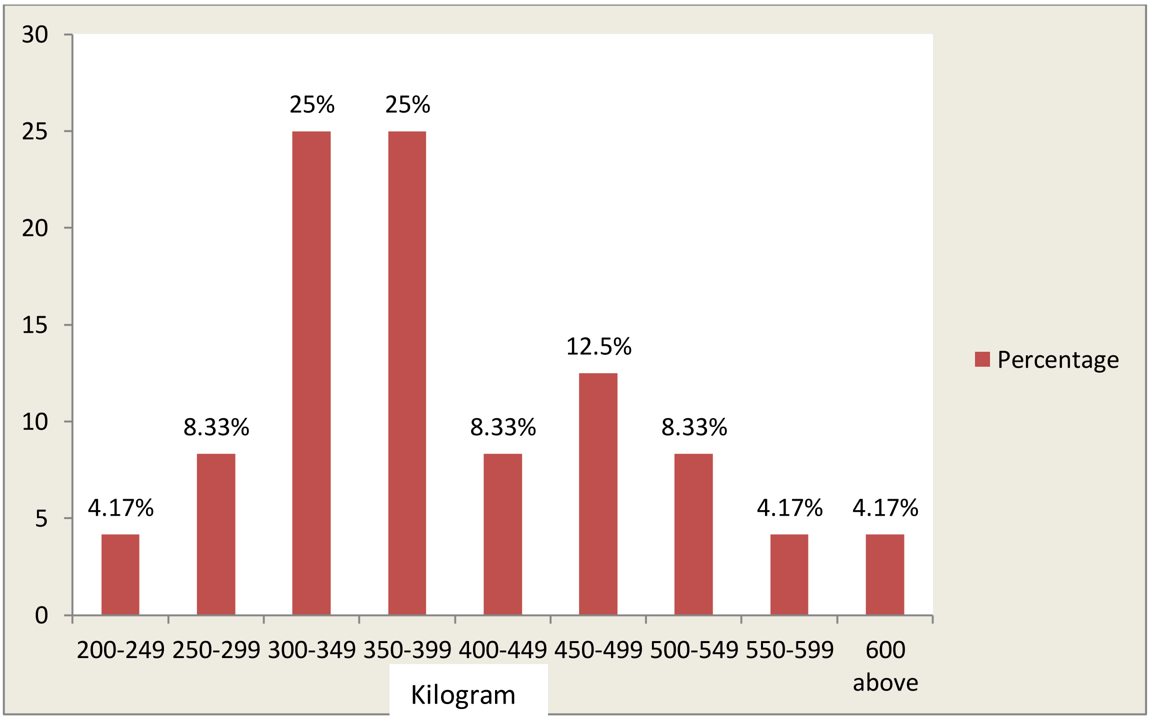


Figure 27: Average production per 10 thousand litre tank (n=24)

From the data on average production from 10 thousand litre tank, 50% of the respondents are producing in between 300 to 400 kilogram fish from a 10 thousand litre tank in each harvest. Furthermore, percentage of total farmers who are producing more than 500 kilogram of fish, accounts for almost 16%. On the other hand, almost 12% of the farmers are producing below 300 kilogram from each harvest from a 10000 litre tank.

Total Annual Production

The analysis of total annual production from a farm confirms 26% of the farms have an annual production of below 1000 kg and 33% of the farmers are producing 1000 to 1499 kg fish per year. The farmers who are producing in between 1500-1999 kg per year accounts for 15% and only 3% are producing more than 6000 kg. Hence considering the quantity of total annual production from a farm, it's clear that contribution of biofloc technology in producing fish is really low and this technology is not adopted in large scale farms yet.

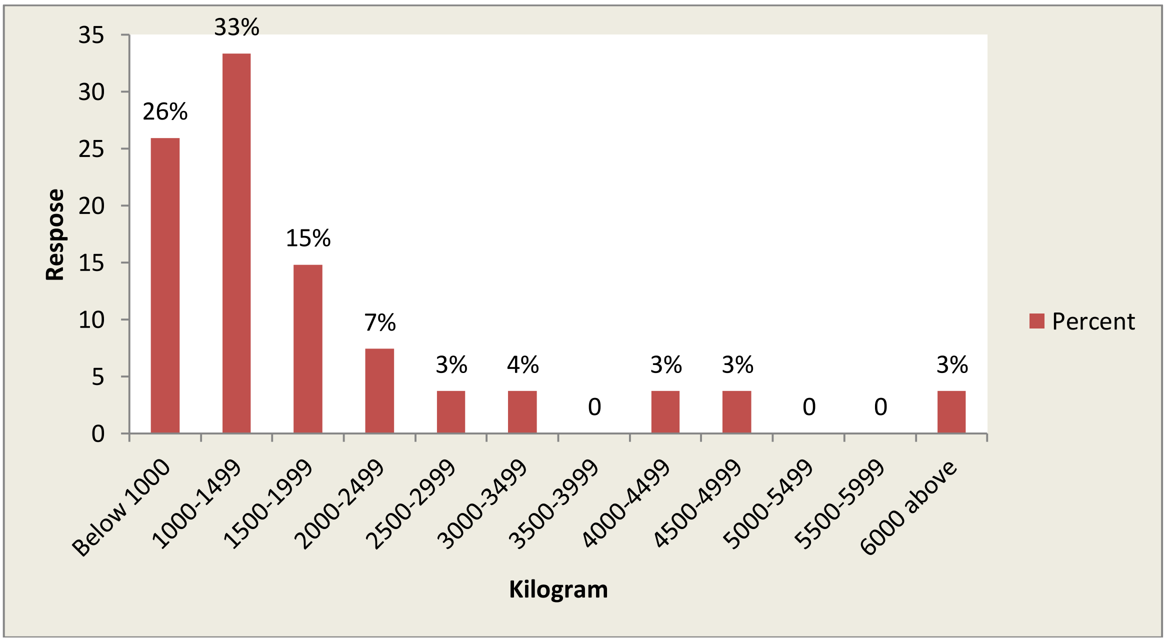


Figure 28: Total annual production from a farm (n=27)

Stock density

From figure 29, we can see that almost 70% of the farmers are satisfied with the stock density of their of their culture tank while only around 30% of the farmers were against it.

From interview, most of the farmers were also satisfied with the stock density except some farmers who were failed to control the carbon and nitrogen ratio and ammonia in the culture tank that caused a lot of fish to die.

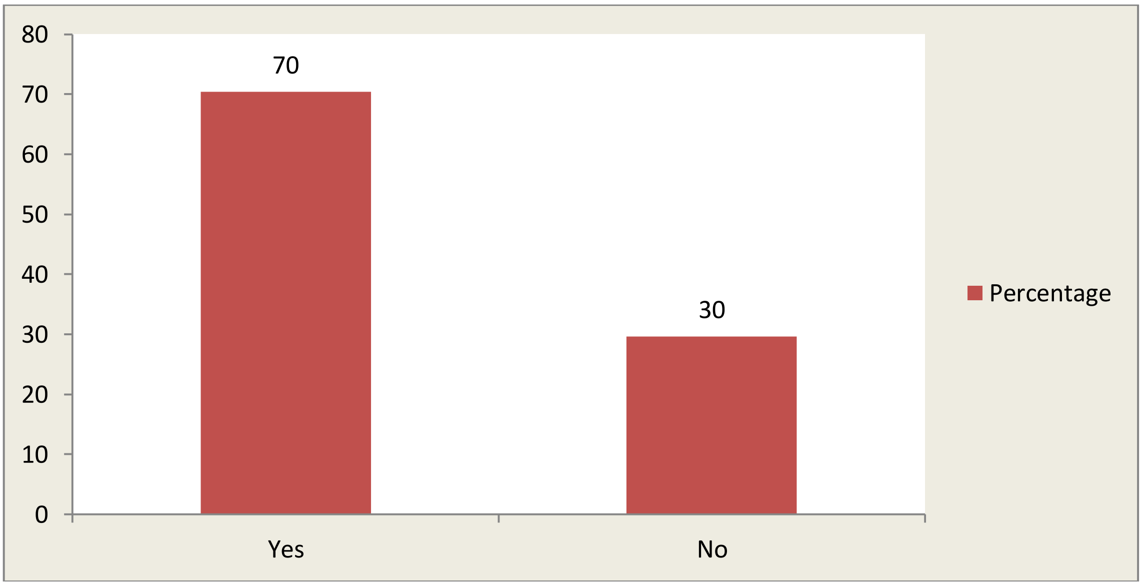


Figure: 29 Satisfaction with stock density (n=27)

Sales and marketing

The data on sales and marketing reveals that almost 79% of the farmers sell their fish to the wholesalers and the farmers who sell their fish directly to the market accounts for only 21%

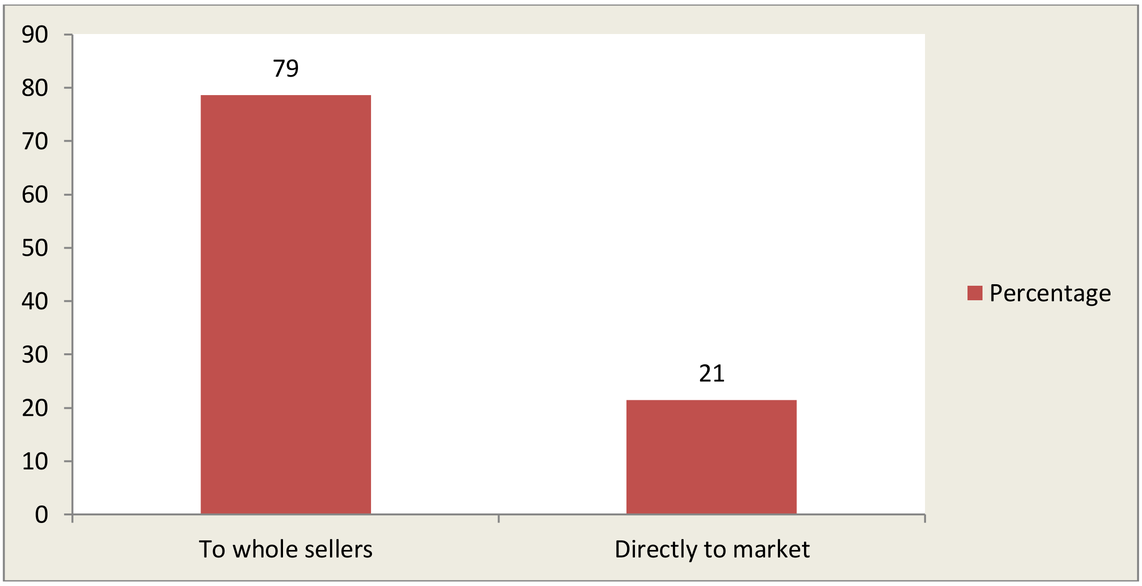


Figure 30: Sale of fish (n=28)

Wholesalers are the intermediary who collects fish directly from the farmers and sell the fish directly to market.

The reason for most of the farmer's willingness to sell the fish to the wholesalers were explored in the interviews where biofloc farmers consider selling of fish directly to market is costly as they need transportation to carry the fish to the market. Moreover avoiding the cost of harvesting is another reason where in most cases the whole sellers pay the cost of harvest under some agreed-upon conditions between farmers and wholesalers.

Financial outcome

While looking at survey data on financial outcome, almost 40% of the respondents are making profit from their farms using biofloc technology and the percentage of total farmers who are in breakeven point or making loss are equal (29.62%).

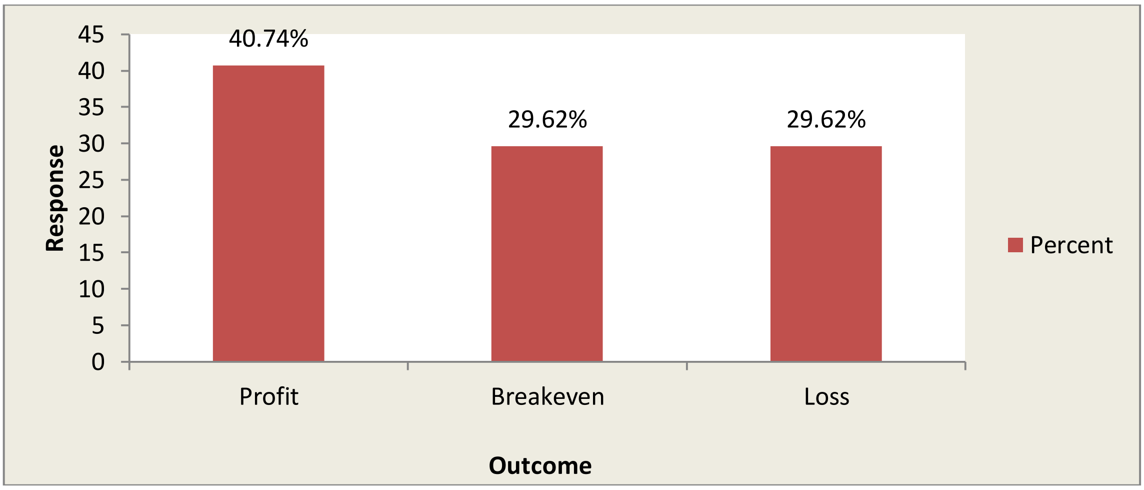


Figure 31: Financial outcome from the farm (n=27)

Is the Income from Biofloc fish farming sufficient to support family?

From the survey data on sufficient income from biofloc fish farming, we can see that for 79% of the respondents' income generated from their farm in not sufficient to support their family.

From the interview, it was confirmed that as most of the farms are small in size and even though most of them are making profit out of their operation, still the income is not enough to support a family. But this income is contributing significantly for the maintenance of family expenses.

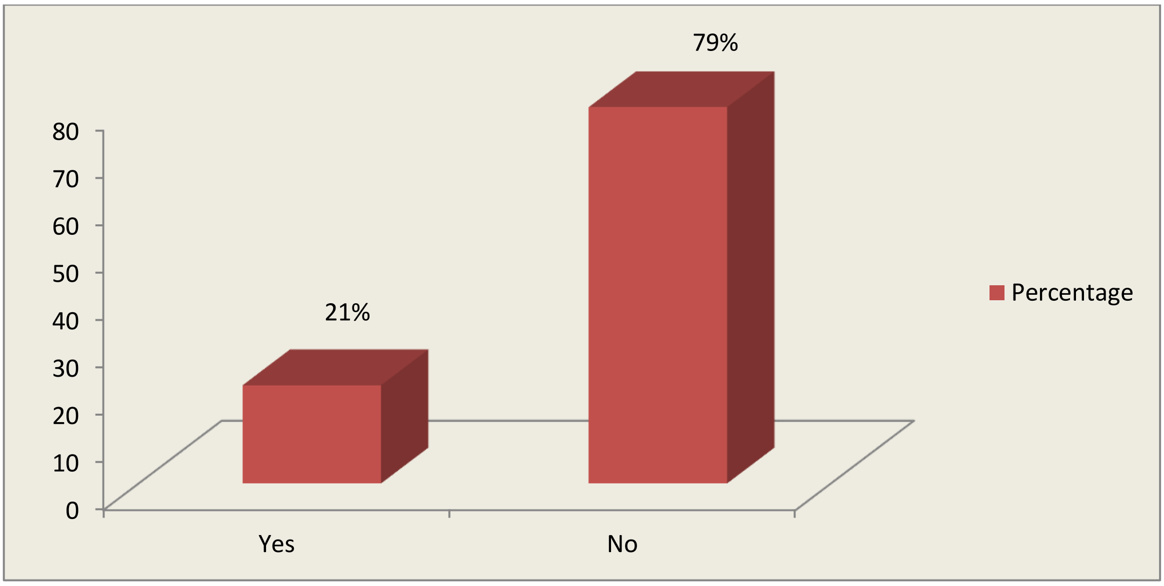


Figure 32: Sufficient income from biofloc (n=29)

Relationship between sufficient income and previous experience in fish farming

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.256136
R Square	0.065606
Adjusted R Square	0.030998
Standard Error	0.405811
Observations	29

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.312192	0.312192	1.895721	0.179868
Residual	27	4.446429	0.164683		
Total	28	4.758621			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.1428	0.0885	1.6131	0.118	-0.038	0.3245	-0.038	0.3245
X Variable 1	0.2321	0.1686	1.3768	0.1798	-0.113	0.578	-0.113	0.578

Table 1: Relationship between sufficient income and previous experience in fish farming

The above regression result (Table:1) shows that the p-value is 0.179 which is greater than 0.05 and thus the relationship is deemed not significant. The R square value of 0.0656 shows that, 6.5% of the variance in the dependent variable (sufficient income) is explained with the independent variable (experience in fish farming). With the p-value greater than 0.05, we accept the null hypothesis that there is no relationship between sufficient income and experience in fish farming according to survey results.

Relationship between sufficient income and training on biofloc technology

The regression results below shows that the p-value is 0.016 which is below 0.05 and thus the relationship is deemed significant. The R square value of 0.196 shows that 19.6% of the variance in the dependent variable (sufficient income) with the independent variable (training in biofloc). With the p-value less than 0.05, we reject the null hypothesis that there is no relationship between sufficient income and training in biofloc according to survey results.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.44294
R Square	0.196196
Adjusted R Square	0.166425
Standard Error	0.376386
Observations	29

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.933621	0.933621	6.5902	0.0161
Residual	27	3.825	0.141667		
Total	28	4.758621			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.125	0.076	1.6269	0.1153	-0.032	0.2826	-0.032	0.2826
X Variable 1	0.475	0.185	2.5671	0.0161	0.095	0.854	0.095	0.854

Table 2: Relationship between sufficient income and training on biofloc technology

As biofloc is a recent practice in Bangladesh, there are misconceptions, rumours about this technology but proper training can help farmers to get out of these misconceptions and adopt this technology to ensure the sustainability of the aquaculture sector.

Relationship with sufficient Income and number of tanks

The regression results below shows that the p-value is 0.0016 which is far below 0.05 and thus the relationship is deemed significant. The R square values of 0.3124 shows that 31% of the variance in the dependent variable (sufficient income) that is explained with the independent variable (number of tanks). With the p-value less than 0.05, we reject the null hypothesis that there is no relationship between sufficient income and number of tanks according to survey results.

More number of tanks allows the farmers to reduce the fixed costs as some fixed costs are same regardless of number of tanks of a farm. Moreover economies of scale are ensured and eventually it increases the productivity and income from the farm.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.558986
R Square	0.312465
Adjusted R Square	0.287001
Standard Error	0.348102
Observations	29

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.486902	1.486902	12.27072	0.001621
Residual	27	3.271719	0.121175		
Total	28	4.758621			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.144	0.119	-1.208	0.2371	-0.388	0.1005	-0.388	0.1005
X Variable 1	0.199	0.0569	3.5029	0.0016	0.0826	0.3165	0.0826	0.3165

Table 3: Relationship with sufficient Income and number of tanks

Correlation of Sufficient income and financial outcome with Year of establishment, experience, and training

Variables	Sufficient income	Financial outcome	Year of establishment	Experience of Fish farming	Training on Biofloc
Sufficient income	1				
Financial outcome	0.37975312	1			
Year of establishment	0.09491227	0.3453001	1		
Experience of Fish farming	0.25613588	-0.1157698	-0.18768337	1	
Training on Biofloc	0.44293978	0.1962156	0.3084305	0.1267731	1

Table 4: Correlation of Sufficient income and financial outcome with Year of establishment, experience, and training

The correlation result shows that although most of the correlation coefficients show that there is positive correlation between the variables, none of them is statistically significant as they are all below 0.5. The correlation coefficients for financial outcome/experience in fish farming and year of establishment/ experience in fish farming has negative coefficients which depicts that they move in opposite direction as an increase in one will result to a decrease in the other and they are not statistically significant being below -0.5.

3.7 Future plan, Support and barriers

Future plan

From earlier data on size of the farms, it’s clear that most of the farmers started their biofloc farms at a small scale. But, regardless of profit, loss or breakeven, 82% of the respondents want to expand their capacity of the farm and 14% of respondents like to quit production. It was really interesting to know that no farmers have a plan for further processing of fish (Figure: 33)

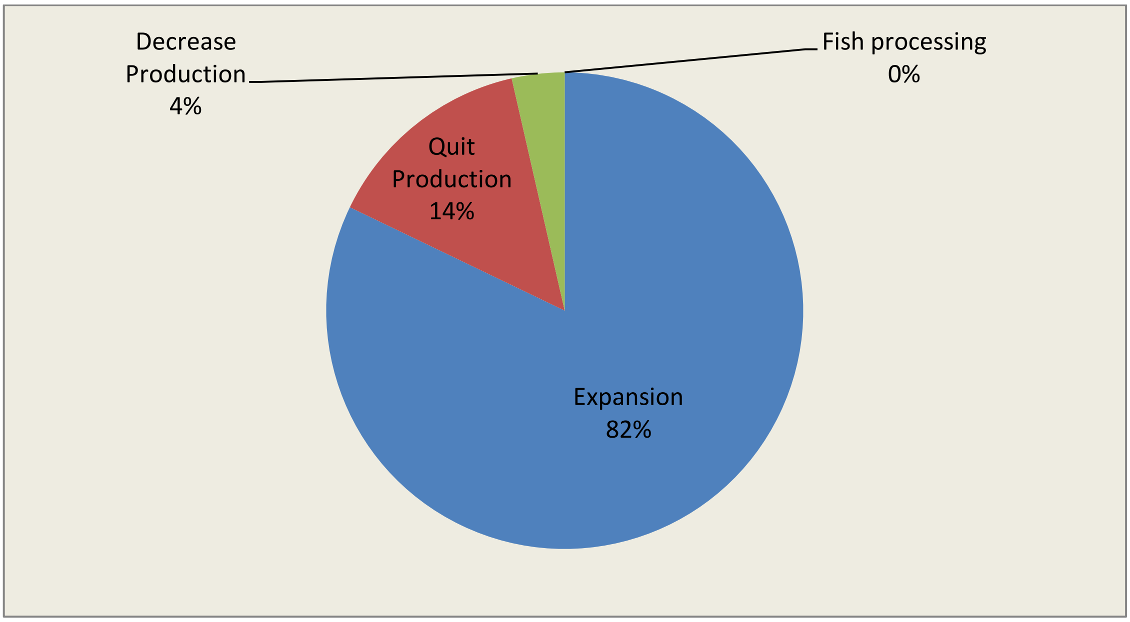


Figure 33: Future Plan with the farm (n=28)

Regression table for future plan and financial outcome

Regression Statistics	
Multiple R	0.200037
R Square	0.040015
Adjusted R Square	0.00446
Standard Error	0.863382
Observations	29

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.838935	0.838935	1.125439	0.298148
Residual	27	20.12658	0.745429		
Total	28	20.96552			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.696203	0.356908	1.950649	0.061549	-0.03611	1.4285	-0.0361	1.4285
X Variable 1	0.392405	0.369891	1.060867	0.298148	-0.36655	1.1513	-0.3665	1.1513

Table 5: Regression table for future plan and financial outcome

The regression results from the above table shows that the p-value is 0.298 which is far greater 0.05 and thus the relationship is deemed not significant. With the p-value greater than 0.05, we accept the null hypothesis that there is no significant relationship between future plans of the farmers and financial outcome from the farm according to survey results.

Barriers for development of Biofloc technology in Bangladesh:

At the end of the survey the farmers were asked an open ended question about the barriers for the development of biofloc technology in Bangladesh where 30% of the respondents think lack of government support (coded as govt. policy) as main barrier and 26% identified lack of proper knowledge of this technology (coded as knowledge gap).19% of the respondents mentioned about poor infrastructure like lack of electricity and 15% identified lack of equipment and accessories as a hindrance for the development of biofloc technology in Bangladesh.

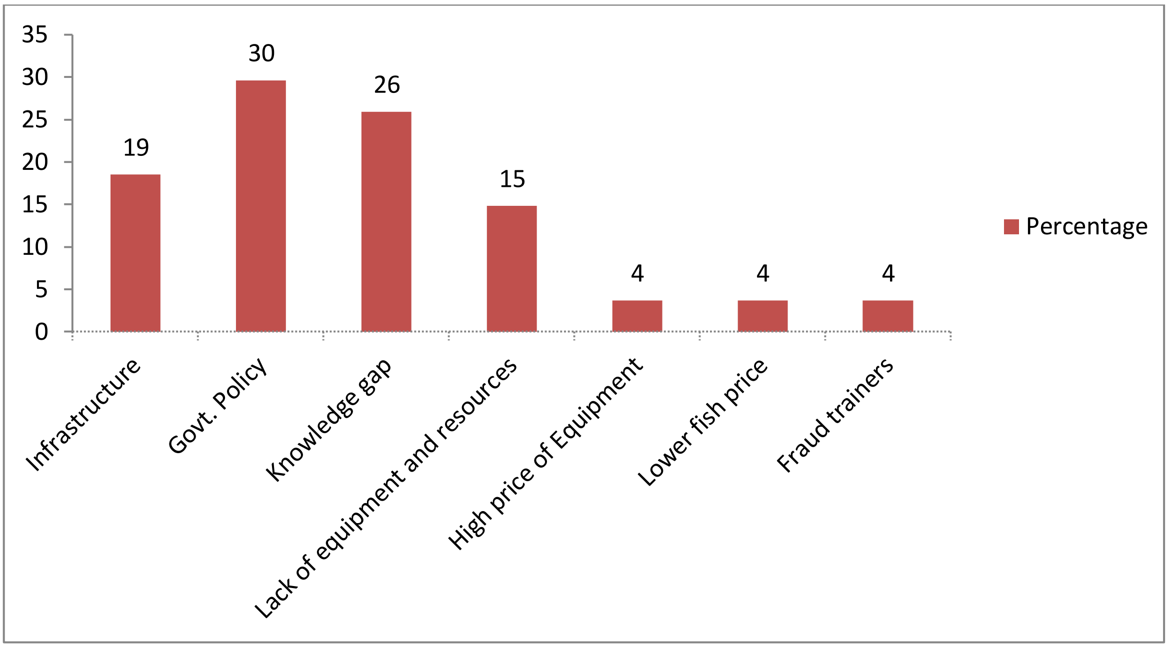


Figure 34: Barriers for biofloc technology (n=27)

4. DISCUSSION

The exponential increase in the world's population has resulted in a large increase in food demand. To satisfy this need, increased production of animal protein, which is the primary source of nutrition for humans, is critical. Moreover, as a result of rising population, there is a shortage of seafood, and strain on fish supplies and eventually Fish prices are rising (Peron et al. 2010). In comparison to the strategic plans for fisheries, it is critical to protect fish stocks, lower fish prices, and raise commercial fish stocks. As a result, BFT technology will release pressure on aquatics supplies as well as improving social security by lowering the cost of fish production which benefits both farmers and consumers. The customer needs assurance that the fish processed is safe for its health and that ethical and social issues are taken into account. In this area, BFT technology has proven to be successful (Khanjani et al. 2020).The biofloc technology has already been recognized as an environmentally friendly, cost-effective and sustainable way to increase water quality because there is almost no water exchange and artificial feeding ratio is limited. Moreover it produces microbial protein for aquatic organisms.

Biofloc technology is an innovative idea and at its early stage in Bangladesh. If we consider the year of the establishment, almost all the farmers started this technology in recent four or five years. In a study, Ekasari, J. 2017 described biofloc technology to be in its infant stage yet. A lot of research and experiments are required to improve this technology and its operational parameters. The findings of this experiment should be should be communicated to the farmers of all levels regardless of their age, gender, academic qualification and area as from the result analysis, we can see that most of farmers who are now engaged in biofloc fish farming are mostly (85%) younger in age (up to 35 year) and educated people who have at least secondary education. As it is stated by UNFPA's "State of World Population Report 2019", In Bangladesh, the rate of youth unemployed people became almost double over the last decade. As the report revealed, the unemployment rate reached at 11% in 2017 from 6% in 1994.This might be a reason for a lot of younger people to get involved into biofloc fish farming. Though number of unemployed people increased over the last decade, biofloc technology certainly helped some younger and unemployed to find a way of alternative way of employment but the number is not significant as most of the farms are established as a sole proprietorship business and at a small scale eventually in 41% of the farm are without employees and 34% of the firm deployed just one employee.

It's mostly the males who are involved in biofloc fish farming and participation of female are really insignificant in this aquaculture practice is really low. Only around 7% of female are engaged with this this biofloc technology and the rest are males. Lower rate of participation of females in aquaculture or related sector is a reason behind their malnourishment. In a study, Ahmed et al. 2012; revealed that approximately one-third women are malnourished in Bangladesh and eventually the 36% of kids under five years age are getting stunned.

The classical old farmers are not that much engaged in biofloc yet. Moreover, this technology is not spread equally all over the country as we can see people from some specific areas are trying to adopt this technology more than other part of the country .This is due to price and availability of resources related to biofloc and good infrastructure including electricity, transportation; as it was identified by Stifel and Minten 2008, that households in countryside with lower access to superior transportation most often have lower productivity.

As biofloc fish farming is relatively a new practice in aquaculture sector of Bangladesh, most of the farmer started their business without having previous experience of traditional fish farming and training on biofloc. The farmers gather most of the technical information through social media platforms like Facebook, whatsapp, watching YouTube videos or other biofloc farmers. Though, from data analysis we did not find a significant co-relation between previous experience of fish farming, training on biofloc and generation of income from biofloc fish farming.

Not all fish species are proven to be suitable for culture using biofloc technology. From this research we found farmers to prefer some specific fish species like Tilapia, koi, shrimp, and catfish. From all these species, tilapia was found to be most popular in biofloc technology because of its high growth rate, high survival and number of harvest in a year. When biofloc was incorporated as food, weight gain and net fish production were 44- 46 % higher in biofloc technology Azim and Little et al., (2008). Furthermore, biofloc helps is improving the longevity of fish as it serves as an antagonist to pathogenic bacteria that stop disease outbreaks and increase the number of fish during harvest. Azim and Little et al.,

(2008) found the survival rate of tilapia to be 100% in all treatment and controlled biofloc tanks.

Biofloc technology can play an effective role in increasing productivity as it is possible to culture fishes in higher density using this practice and most of the farmers were satisfied (almost 70%) with the stock density of their culture tank. Even from a previous study by Park et al. 2017**,** biofloc technology was found to be efficient in increasing productivity of fish by establishing a positive relationship between biofloc and fish density.

From this research, we also found biofloc to be with higher productivity as almost 50% of the farmers are producing 300 to 400 kilogram of fish in each harvest from a 10000 litre capacity tanks and around 1000 to 1200 kg per year as most of the farmer usually target three harvests in a year. But farmers with larger production capacity are producing around 5000 to 600 kilogram of fish. Though most of the farmer started biofloc fish farming in a small scale or as an experiment, still 40% of the farmers are making profit out of their operation and it's due to productivity of biofloc technology.

As we stated before, biofloc is at its early stage in Bangladesh the technology is not yet well understood by a lot of farmers. Infrastructure, government policy, shortage of resources and lack of proper knowledge on biofloc technology hinder the development of this technology. But by considering all the features of this technology including productivity, high survival rate of fish, lower feed cost, zero water exchange and environment protection biofloc technology can offer an ample opportunity to create employment, eradicate poverty and improve human health by ensuring nutrition uptake.

Conclusions

Aquaculture and fishery resources play a significant role in the overall development of Bangladesh by creating employment, earning foreign exchange, alleviating poverty, protein deficiency and malnutrition. But, exponential growth of population is subsequently creating shortage of seafood and higher fish prices. Natural calamities like flood, scarcity of water due to droughts, pollution etc. hinders the development of aquaculture. Researches have been carried out to find a way of accelerating the aquaculture production with the application of new technologies.

Biofloc technology which is considered as an environment friendly and cost effective way of aquaculture can contribute to productivity and ensure sustainability. As this technology is at early stage of diffusion in Bangladesh, there are uncertainties about adoption of this technology by farmer of all ages and areas as from our research we found farmers from specific age and area are more interested in this technology. So far, the farmers who adopted this technology, started in a small scale and as a side activity beside their main profession and mostly without having any previous experience and training but still a significant number of farmers are making profit out of their operation.

Machineries and accessories related to biofloc technology are not available in all the areas and eventually framers need to pay higher price. Moreover, there is scarcity of good quality fingerlings and farmers are often deceived by the fingerlings suppliers. Those who adopted biofloc technology, are getting all these thing arranged by themselves without any support from the government or any other organization. So, proper government policy to support this technology can contribute to adoption of this aquaculture practice, production of fish and growth in this industry.

Although there are uncertainties, rumours and misconception regarding biofloc technology, present study found it to be productive and as an emerging prospect for aquaculture production. However, further research and clear understanding of operation of this technology can improve social well-being by reducing the fish production cost that can benefit both farmers and consumers.

Recommendations

As biofloc technology is relatively a new practice in the aquaculture practice of Bangladesh there are a lot of areas to improve as to make this technology accepted by the farmers. Based on the present study following steps might be taken for the adoption and development of this technology.

- Proper strategy should be formulated to ensure government support for the development of this technology.
- Practical training should be provided to the farmers including initial tank setup to maintenance and harvest to minimize the knowledge gap among farmers about this technology.
- Availability of machineries and accessories for this technology should be ensured and the price should be made reasonable.
- Further researches should be carried out to explore the economic benefits of this technology and the results should be communicated with the farmers to persuade them to adopt this practice as a new generation aquaculture.

Limitation of study

The major limitation of the study is limited number of responses and it was not possible to visit the farm in person due to Covid-19 pandemic. Moreover as the survey questionnaire was administered through online platforms, it was difficult to reach farmer from all ages and regions as accessibility to internet differs from area to area and it’s mostly the educated people who responded to the survey. On the other hand statistical data on biofloc technology in Bangladesh was not available.

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APPENDICES

Appendix 1. Sample of the questionnaire

Biofloc fish farming

As a part of my Master thesis at Estonian University of Life Sciences, I am conducting a survey that explores the information about Biofloc fish farming .I will appreciate if you please respond to the following survey. Any information obtained in connection with this study that can be identified with you will remain confidential.

1. Name:

2. Age:

3. Gender:

   Check all that apply.

   - [ ] Male
   - [ ] Female

4. Education Level:

5. Area:

6. 1. Year of establishment of the farm

7. 2. Indicate the type of your business

Check all that apply.

- [ ] Sole proprietorship
- [ ] Partnership
- [ ] Company

8. 3. How many employees are there in your Farm?

____

9. 4. What is your role at the farm? (Select all that apply)

Check all that apply.

- [ ] Sole proprietor / self – employed
- [ ] Partner
- [ ] Manager
- [ ] Employee

10. 5. Do you work outside the biofloc farm?

Check all that apply.

- [ ] Yes
- [ ] No

11. 6. Is biofloc your main business or a side activity?

Check all that apply.

- [ ] Main Business
- [ ] Side Activity

12. 7. Does biofloc enable you to obtain sufficient income for the family?

Check all that apply.

- [ ] Yes
- [ ] No

13. 8. Do you have previous experiences of fish farming before starting Biofloc?

Check all that apply.

- [ ] Yes
- [ ] No

14. 9. Did you get any training on Biofloc before starting?

Check all that apply.

- [ ] Yes
- [ ] No

15. 10. Number of Tanks at your farm

____

16. 11. Total capacity of your tank (In thousand litres)

____

17. 12. Are the machinery/accessories related to Bio-floc easily available in market?

Check all that apply.

- [ ] Yes
- [ ] No

18. 13. What about the price of machinerie/accessories?

Check all that apply.

- [ ] Cheap
- [ ] High
- [ ] Reasonable

19. 14. Which fish species you prefer most in Biofloc?

____

20. 15. Where do you collect the fingerlings?

Check all that apply.

- [ ] Local Suppliers
- [ ] Self Breed

21. 16. Are the fingerlings easily available?

Check all that apply.

- [ ] Yes
- [ ] No

22. 17. Did you ever harvest?

Check all that apply.

- [ ] Yes
- [ ] No

23. 18. If yes, Average approximate fish production per 10 thousand litres (In kilogram)

____

24. 19. Targeted number of harvest per year from a tank

25. 20. Total Annual production from your farm (In kilogram)

26. 21. Are you satisfied with stock density?

Check all that apply.

- [ ] Yes
- [ ] No

27. 22. Financial outcome from your farm?

Check all that apply.

- [ ] Profit
- [ ] Loss
- [ ] Break-even

28. 23. Where do you sell the fishes?

Check all that apply.

- [ ] Directly to local market
- [ ] To whole sellers

29. 24. What's your future plan with boifloc?

Check all that apply.

- [ ] Expansion
- [ ] Decrease production
- [ ] Quit production
- [ ] Fish processing

30. 25. Where do you get technical information about biofloc?

Check all that apply.

- [ ] Local Experts
- [ ] Social media
- [ ] Biofloc farmers

31. 26. Do you get any support financial or technical support from any govt. /non-govt. organization?

Check all that apply.

- [ ] Financial support
- [ ] Technical Support
- [ ] Both financial and technical
- [ ] No Support

32. 27. What are the main barriers for developing Biofloc technology in Bangladesh?

Appendix 2. Non-exclusive licence for depositing the final thesis and opening it for the public and the supervisor's (supervisors') confirmation for allowing the thesis for the defence

Hereby I, Mohammad Soyebur Rahaman.

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